PB-242 576

TECHNICAL AND ECONOMIC EVALUATION OF RECYCLED INDUSTRIAL SECONDARY PRODUCTS FOR THE PREPARATION OF SYNTHETIC HIGHWAY BUILDING AGGREGATES

IU Conversion Systems, Incorporated

Prepared for:

Appalachian Regional Commission

July 1974

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US Department of Commerce
Springfield, VA. 22151

BIBLIOGRAPHIC DATA SHEET	1. Report No. ARC 73-40 [RPC 772]	2. PB 242 576

4. Title and Subtitle

Technical and Economic Evaluation of Recycled Industrial Secondary Products for the Preparation of Synthetic Highway Building Aggregates.

5. Report Date

6.

7. Author(s)

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8. Performing Organization Rept. No.

9. Performing Organization Name and Address

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10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

Appalachian Regional Commission
1666 Connecticut Ave.,NW
Washington, DC 20235

13. Type of Report & Period Covered

14.

15. Supplementary Notes

Performed under EPA Contract 14010-HQC-12

16. Abstracts

This study investigated and tabulated data relating to the supply and proposed use of lime fly ash sulfate sludge compositions as a substitute for conventional road building materials. It was found that this would be economically feasible and environmentally beneficial. This would solve pollution problems and at the same time provide highway construction material within the state of West Virginia.

17. Key Words and Document Analysis. 17a. Descriptors

Lime - Fly ash - sludge (2102)

Highway Pavements (1302)

Waste Utilization (1407)

17b. Identifiers/Open-Ended Terms

17c. COSATI Field Group

PRICES SUBJECT TO CHANGE

18. Availability Statement	19. Security Class (This Report) UNCLASSIFIED	21. No. of Pages 73
	20. Security Class (This Page) UNCLASSIFIED	22. Price 4.25

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ARC REVIEW NOTICE

This report has been reviewed by the Appalachian Regional Commission (ARC) and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the ARC, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

REVIEW
EXECUTIVE/SUMMARY

The utilization of lime-fly ash sludge mixtures as a replacement for conventional highway materials is entirely feasible and economically competitive in the West Virginia area.

The amounts of road base materials that could be manufactured with currently available waste materials would be sufficient to meet the needs of current highway construction.

In the future, there are also opportunities for use of this waste product technology for the production of stabilized structural materials for strip mine reclamation, prevention of deep mine subsidence, and production of synthetic aggregate.

The stabilized waste mixtures can include aggregate materials such as mine tailings or slag as a part of the composition if this is desirable from a waste utilization point of view. The large tonnages of fly ash that are available in the area would also permit the manufacture of sintered lightweight aggregate from the ash.

With the advent of lime or limestone throwaway scrubbing systems for SO_2 removal, the amounts of potentially polluting sludge materials will increase well beyond the present levels, and these alternate uses for lime-fly ash-sludge compositions may well present a much needed solution to the potential environmental problems which the sludge creates.

It is the suggestion of IU Conversion Systems, Inc. (IUCS) that a demonstration of Poz-O-Tec™ services be undertaken to illustrate its performance as a viable construction material. This demonstration would provide an opportunity for testing of the material under actual service condition; it would allow an evaluation of the limiting conditions for use of the material, and provide a basis for assigning appropriate design parameters. Although final choice of a demonstration site cannot be made without consultation with the appropriate authorities, IUCS feels that, at present, the Charleston or Morgantown areas would lend themselves most ideally to this activity.

PREFACE

This study is one of a series of reports being prepared for the Appalachian Regional Commission for the development of an overall environmental pollution abatement plan for the Monongahela River Basin with special attention to mine drainage. The Basin is an 18-county area encompassing parts of Appalachian West Virginia, Pennsylvania and Maryland.

These studies are being performed under an agreement between the Environmental Protection Agency and the Commission and are part of a larger EPA effort to deal with elimination and control of mine drainage within the watershed. The Commission's major responsibility in this interagency effort is to evaluate the exonomic development impacts of mine drainage and other pollution abatement which will include for planning purposes those engineering studies necessary to determine cost effectiveness among possible alternative approaches and to assess the full range of activities required to improve the environment within the Basin consistent with water and land use objectives. It is felt that if pollutants and other environmentally degrading problems can be alleviated, other public and private investments will provide greater opportunities to improve the economy of the Basin. The results of these studies then should suggest courses of action for selecting priorities for environmental and associated projects to Federal, State, and local decision-makers and the private sector as well as clarifying the Basin's potential for economic development.

I. INTRODUCTION

This report presents a summary of data relating to the contract awarded to IU Conversion Systems, Inc. (IUCS), by the Appalachian Regional Commission (ARC) (No. 73-10/RPC772), "Technical and Economic Evaluation of Recycled Industrial Secondary Products for the Preparation of Synthetic Highway Building Materials."

The following sections contain the data and conclusions from IUCS concerning the availability of lime-fly ash, and sludge materials in the State of West Virginia and other adjacent areas of the Monongahela River Basin. Also included, for purposes of presenting a comprehensive description of the existing situation, are surveys that present data relating to highway construction and present methods, etc. for which waste processing could offer attractive alternatives.

All survey work performed under the terms of this contract has been tabulated and is presented in summary in this report.

In addition, data relating to the projected costs of using waste materials for highway construction has been included to allow economic comparisons with conventional construction techniques.

A preliminary technical evaluation and specification section relates the studied construction materials to standards for materials currently in use.

This final report also includes a statement of the potential directions that might now be taken with regard to facilitating a program to introduce waste processing technology.

II. BACKGROUND

The first use of lime-fly ash compositions for road base construction was carried out by the G. & W. H. Corson Company in cooperation with the Philadelphia Electric Company. The first formulations dealt with "in-place" mixing of the lime and fly ash with soil. Later new formulations were developed which incorporated various aggregate and waste materials which in many instances proved to be better than the natural soil. All of these compositions (known to the construction industry as Poz-O-Pac®) were widely used to construct shoulders of roads, secondary and private road bases, airfields, embankments, as well as large dams and municipal reservoirs. Continuous research by the Corson Company and other organizations such as the University of Illinois gradually established a meaningful technology which provided contractors and specification writers with the basic information needed for these materials. Numerous patents were issued which demonstrated the broadening fields of applications to which Poz-O-Pac® could be used. Later, the projects which were in service for extended time periods offered a source of information which tied in closely with the laboratory test programs.

During the 1960's several important developments occurred which substantially altered the manner in which these compositions were employed. First, a study by American Association of State Highway Officials (AASHO) at a test track in Illinois clearly demonstrated the superiority of stabilized bases over conventional stone base for adequate support of modern traffic loading. Second, the introduction of "plant" mixing rather the "in-place" mixing provided an opportunity to use aggregate instead of soil (or soil aggregate) in the lime-fly ash compositions. The extensive experience which Poz-O-Pac® had established at this time resulted therefore in a large increase throughout the country in this type of road base. Competitive materials such as portland cement and asphalt stabilized bases also played a part in this growth period, although lime-fly ash aggregate did show a number of advantages which appealed to the paving organizations. Very briefly these included ease of construction (such as less concern with weather interference); the ability to put into immediate service; favorable economics and, from the customers standpoint, excellent performance together with ease of maintenance under a wide range of environmental and traffic conditions.

Recently further developments have provided new opportunities for lime-fly ash structural compositions primarily due to the recognition that large tonnages of industrial waste can now be utilized beneficially for social good. Thus millions of tons of fly ash can be disposed of annually to land fill and construction projects rather than to environmentally undersirable waste ponds and lagoons or disposal areas. Further, incorporating sulfur oxide wastes (as evaluated in this report) helps to resolve a serious environmental problem which the electric utilities (and also the chemical process industries) are concerned with at this time. IUCS was established to implement the developments of the last twenty-five years specifically as a service organization (Poz-O-Tec™).

As outlined in this report, opportunities for application of the existing lime-fly ash technology certainly exist in the "Appalachian" region. In addition the new formulations can be employed without using soil or natural aggregate. Previous investigations by the Corson Company have also shown that synthetic aggregates can be produced from lime-fly ash-sulfur oxide waste mixtures These developments have resulted in an additional opportunity for those geographic areas where aggregates are in short supply.

III. SURVEYS

A. Fly Ash Survey

The West Virginia area was surveyed by IUCS to determine the amount of fly ash which could be used for road base materials. Coal-burning power plants, by far the major sources of fly ash and probably the only sources that can be seriously considered as long-range quantity suppliers, were investigated in detail. Exhibit 1 is a summary of fly ash production by companies in West Virginia and the immediately surrounding areas. The information is presented graphically in Exhibit 2.

Chemical analyses were obtained from power stations burning coal representative of specific areas of supply (Exhibit 3). Although all analyses showed that the ash was adequate for inclusion in a road base mix, a few of these representative chemical analyses are included to indicate typical constituents of West Virginia ash.

Exhibit 4 is a listing of present disposal techniques for fly ash. Cost of disposal was not determined because it is generally considered information proprietary to the power companies.

Exhibit 5 is a graphical presentation of the estimated hauling costs for fly ash. Similar data for sluicing was not obtainable since that function is performed internally.

EXHIBIT I

ESTIMATED FLY ASH PRODUCTION BY COMPANIES*

ALLEGHENY POWER SYSTEM

(Monogahela Power, West Penn Power, Potomac Edison)

Willow Island Station	(M)		22,000 tons	
Harrison Station	(M)		300,000 tons	(I MM 1975)
Rivesville Station	(M)		47,300 tons	
Ft. Martin Station	(M)		300,000 tons	
Hatfield Station	(WP)		255,000 tons	
Mitchell Station	(WP)		77,000 tons	
Springdale Station	(WP)		41,000 tons	
Albright Station	(M)		157,000 tons	
R. Paul Smith Station	(PE)		30,000 tons	
Armstrong Station	(WP)		120,000 tons	
Milesburg Station	(WP)	being con-	19,800 tons	
Riverton Station	(PE)	verted to oil	11,400 tons	
		Total Estimated Tons	1, 080,500	

AMERICAN ELECTRIC POWER SYSTEM

(Ohio Power, Appalachian Power, Kentucky Power)

Cardinal Station	(OP)		350,000 tons	
Tidd Station	(OP)		48,000 tons	
Windsor Station	(OP, WP)	(no longer in service)	32,000 tons	
Kammer Station	(AP)		157,000 tons	
Mitchell Station	(AP)		168,000 tons	
Muskingum Station	(OP)		380,000 tons	
Philip Sporn Station	(OP)		340,000 tons	
Gavin Station	(OP)	Under construction	350,000 tons	(expected)
Big Sandy Station	(KP)		280,000 tons	
Amos Station	(AP)	Under construction	300,000 tons	
Kanawha Run Station	(AP)		180,000 tons	
Cabin Creek Station	(AP)		38,000 tons	
Glen Lynn Station	(AP)		83,000 tons	
		Total Estimated Tons	2 ,356,000 tons	

OHIO EDISON

Sammis Station			500,000 tons	
Toronto Station			50,000 tons	
Burger Station			150,000 tons	
		Total Estimated Tons	700,000	

OHIO VALLEY ELECTRIC COMPANY

Kyger Creek Station			300,000 tons	

VIRGINIA ELECTRIC POWER COMPANY

Mt. Storm Station			300,000 tons	

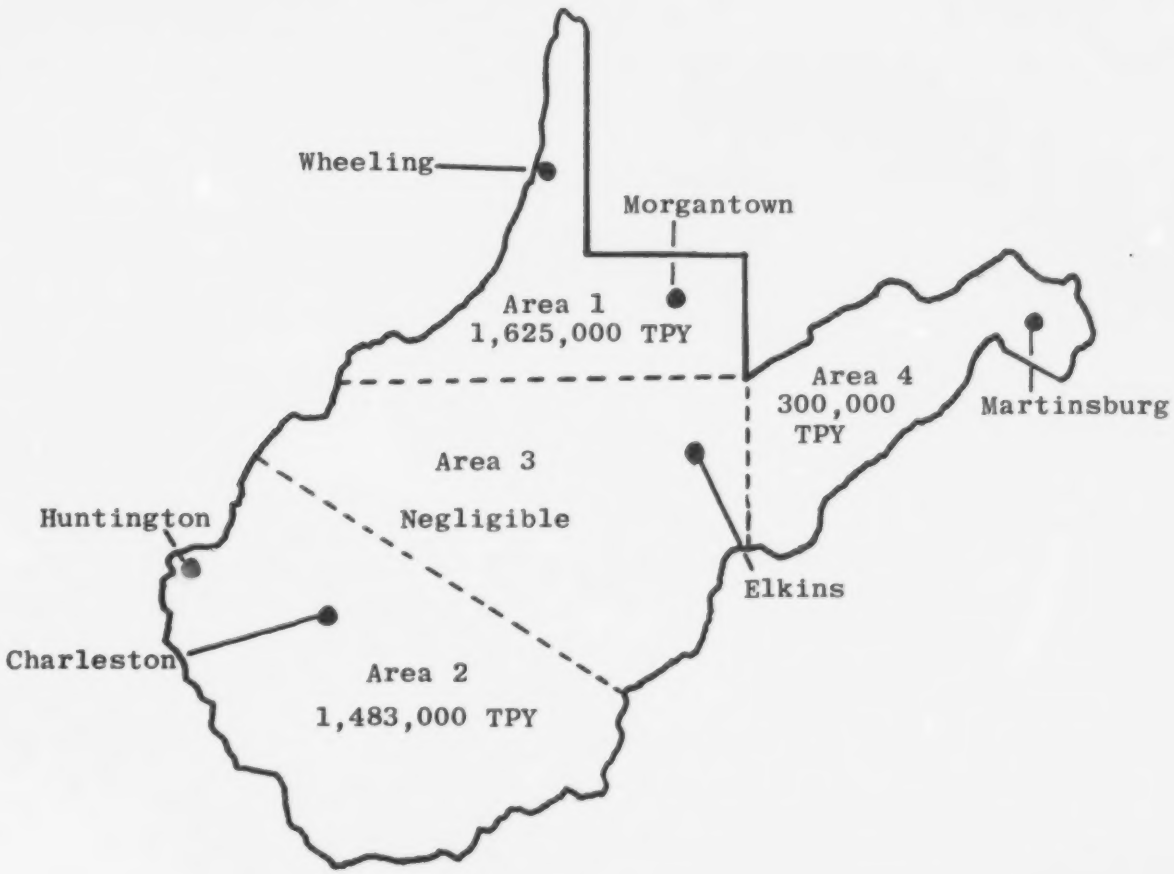
ESTIMATED TOTAL PRODUCED 4, 736,500

Source: Information supplied courtesy of Monongahela Power Company, Fairmont, West Virginia and National Ash Association, Washington D. C.
Data from 1971 with updating to 1972-73 by IUCS.

EXHIBIT 2

FLY ASH PRODUCTION MAP

(Tons Per Year Per Area)



Source: Fly Ash Survey, 1971, Monongahela Power Co., Fairmount, West Virginia

EXHIBIT 3

FLY ASH ANALYSES

(Figures in Percent)

	Albright	Burger	Ft. Martin	Kanawha	John Amos	Phillip Sporn
pH	10.9	9.2	10.8	6.30	7.42	10.0
SiO_2	53.6	46.6	49.4	54.80	55.20	49.30
R_2O_3	40.9	37.3	40.0	37.20	38.10	40.30
CaO	1.3	4.6	3.9	1.10	1.20	3.50
MgO	0.7	1.2	1.2	1.70	0.70	Trace
Na_2O	0.2	0.3	0.6	0.20	1.10	0.30
K_2O	2.3	NA	2.3	2.80	1.40	2.30
P_2O_5	0.4	0.3	0.3	NA	NA	NA
TiO	0.8	0.9	0.7	0.00	0.00	0.00
SO_3	0.1	1.9	0.1	0.60	0.40	0.80
LOI (at 900°C)	2.0	8.3	1.2	1.30	2.10	2.20

Source: Analyses for Albright and Ft. Martin Stations from U. S. Department of Interior, Bureau of Mines, Morgantown, W. Va.

Analyses for Kanawha, John Amos, and Phillip Sporn Stations from AEP Service Corporation, Charleston, W. Va.

Analyses for Burger Station from IU Conversion Systems, Inc., Phila., Pa.

EXHIBIT 4

PRESENT ASH DISPOSAL TECHNIQUE

POWER COMPANY	STATION	FLY ASH	BOTTOM ASH
OE	Toronto Station	NC	NC
OP	Cardinal Station	sluiced	sluiced
OP	Tidd Station	NC	NC
OP	Windsor Station	NC	NC
OE	Burger Station	sluiced	hauled
AP	Kammer Station	none	hauled
AP	Mitchell Station	sluiced	sluiced
MP	Willow Island Station	sluiced	hauled
OP	Muskingum Station	sluiced	hauled
AP	Phillip Sporn Station	sluiced	sluiced
OVE	Kyger Creek Station	sluiced	sluiced
OP	Gavin Station	sluiced	sluiced
KP	Big Sandy Station	sluiced	hauled
AP	John Amos Station	sluiced	hauled
AP	Kanawha Run Station	hauled	hauled
AP	Cabin Creek Station	NC	NC
AP	Glen Lyn Station	NC	NC
MP	Harrison Station	hauled	hauled
MP	Rivesville Station	NC	NC
MP	Fort Martin Station	hauled	hauled
WPP	Hatfield Station	hauled	hauled
WPP	Mitchell Station	NC	NC
WPP	Springdale Station	NC	NC
MP	Albright Station	hauled	hauled
VEP	Mt. Storm Station	hauled	hauled

LEGEND:

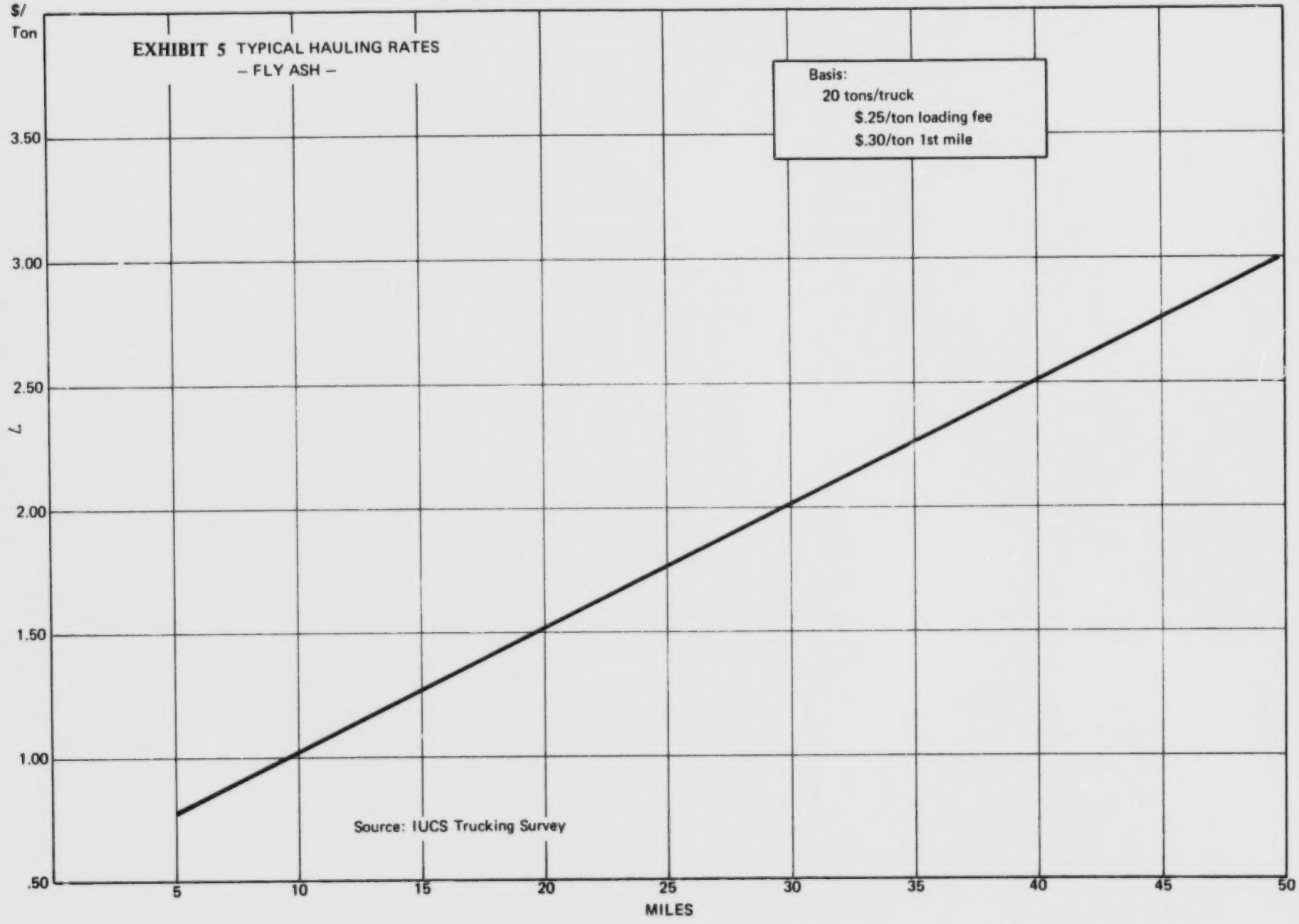
Sluiced	Mixed with water and ponded
Hauled	Trucked to distant disposal site or sold
NC	Not considered (small prod., distance, etc.)
NA	Information not available at this time

POWER COMPANIES:

VEP	Virginia Electric Power
KP	Kentucky Power
OE	Ohio Edison
OP	Ohio Power
AP	Appalachian Power
MP	Monongahela Power
OVE	Ohio Valley Electric
WPP	West Penn Power

SOURCE:

IUCS survey


$/
Ton
EXHIBIT 5 TYPICAL HAULING RATES
– FLY ASH –
Basis:
20 tons/truck
$.25/ton loading fee
$.30/ton 1st mile
3.50
3.00
2.50
2.00
1.50
1.00
.50
T
Source: IUCS Trucking Survey
5
10
15
20
25
30
35
40
45
50
MILES

B. SURVEY OF WASTE SULFER OXIDE COMPOUNDS

1. General

The materials involved in this survey are produced from varied sources, including mine drainage treatment plants, chemical plants, and power plant gas-scrubbing operations. While the report summarizes the major sources of waste sulfur oxide compounds, it is impractical to tabulate all locations within the state. Mine drainage problems, for example, abound in all parts of the state from strip mining and underground operations. Many of these sites remain untreated for economic reasons, etc. It is believed however that Poz-O-Tec™ waste processing technology can offer an attractive solution to this growing problem.

2. Power Plants

With the advent of sludge producing SO_2 scrubbers, the quantities of this waste material will increase substantially. However the available technology is compatible with the scrubber sludges and could accept all presently conceived quantities of this waste material. The amount could be quite voluminous since the solids in the scrubber sludge will approximate five (5) times the weight of sulfur in the coal.

NOTE: At the present time no scrubbers are in operation in the Appalachian Region using lime or limestone for SO_2 removal.

3. The Chemical Process Industries

The process industries which were contacted could not in all cases provide information on their waste products. This resulted in some limitations in developing the survey. In spite of this situation, the survey is believed to be a reasonable overview of the industrial plants of the area that may serve as suitable sources of material to implement a viable program in West Virginia.

The following list (Exhibit 6) of chemical plants and facilities all produce sulfur-containing products and/or generate a sulfur-containing by-product. These by-products are not necessarily related to waste material which may be detrimental to the environment, but represent sources of sulfur oxide compounds that may be disposed of by means of incorporation into the structural materials discussed in this report.

EXHIBIT 6

CHEMICAL PROCESS INDUSTRIES

Allied Chemical Corporation
Industrial Chemicals Division
Nitro, West Virginia

Manufactures hydroflouric acid, sulfuric acid, soda ash and molten sulfur. Hydroflouric acid manufacture produces calcium sulfate anhydrite as waste product. Current stockpiles of this waste are in excess of 2 million tons.

Diamond Alkali Company
Belle, West Virginia

Manufactures hydrochloric acid by salt process. This process produces sodium sulfate (Na_2SO_4) as a by-product.

E. I. du Pont de Nemours & Company, Inc.
Industrial and Biochemicals Department
Belle, West Virginia

Produces a calcium sulfate sludge slightly contaminated with acetate impurities.

FMC Corporation
Inorganic Chemicals Division
South Charleston, West Virginia

Manufactures chlorine and caustic soda by brine process (electrolysis). This process produces a waste stream of spent sulfuric acid which is currently placed in a waste-holding pond.

Union Carbide Corporation
South Charleston & Institute, West Virginia
Chemicals - Plastic Division

Products include polysulfide rubbers.

Solvay Process Division
Moundsville, West Virginia

Plant produces chlorine and caustic soda by electrolysis of brine. This process generates a waste stream of spent sulfuric acid.

E. I. du Pont de Nemours, Inc.
Plastics Department
Parkersburg, West Virginia & Wurtland, Kentucky

Sulfuric acid manufactured in various grades at Wurtland plant.

Stauffer Chemical Company
Specialty Chemical Division
Gallipolis Ferry, West Virginia

Hydrocholoric acid manufacture produces sodium sulfate (Na_2SO_4) as a by-product.

4. Acid Mine Drainage

The development of coal mine drainage results from the chemical, biochemical, and physical reactions of the mineral pyrites (FeS_2) with water and oxygen in the environment. The reaction products are polluting substances which may immediately dissolve in the ground water.

The main progenitor of the pollution, pyrites, occurs throughout all coal seams as discrete particles ranging in size from several feet to less than one micron. It is the freeing, fracturing, and liberating of the pyrite particles that occurs during mining which exposes more pyrite surfaces that enhance the formation of coal mine drainage as a result of the mining operations.

This type of problem exists in strip and deep mining operations. The plants that have been erected to treat this drainage problem are listed in Exhibit 7 and located geographically in Exhibit 8.

EXHIBIT 7

WEST VIRGINIA

KNOWN ACTIVE UNDERGROUND MINE TREATED DISCHARGES

CONSOLIDATION COAL COMPANY

Pursglove No. 15 Mine (Christopher Division)
Total Flow: 3,395,000 gallons per day (% Treated-Unknown)
Method of Treatment: Neutralization with hydrated lime
Aeration
Settlement

Arkwright Mine (Christopher Division)
Total Flow: 6,165,000 gallons per day (% Treated-10%)
Method of Treatment: Neutralization with hydrated lime

Four States No. 20 Mine (Mountaineer Division)
Total Flow: 585,000 gallons per day (% Treated-100%)
Method of Treatment: Neutralization with hydrated lime
Ponding

Williams No. 98 Mine (Mountaineer Division)
Total Flow: 2,643,000 gallons per day (% Treated-70%)
Method of Treatment: Neutralization with hydrated lime

Robinson Run No. 95 Mine (Mountaineer Division)
Total Flow: 622,000 gallons per day (% Treated-40%)
Method of Treatment: Neutralization with hydrated lime
Aeration
Sedimentation

EASTERN ASSOCIATED COAL CORPORATION

Federal No. 1 Mine

Total Flow: 795,000 gallons per day (% Treated-50%)
Method of Treatment: Neutralization with hydrated lime
Aeration
Settlement

RELIABLE COAL COMPANY

Kanes Creek Mine

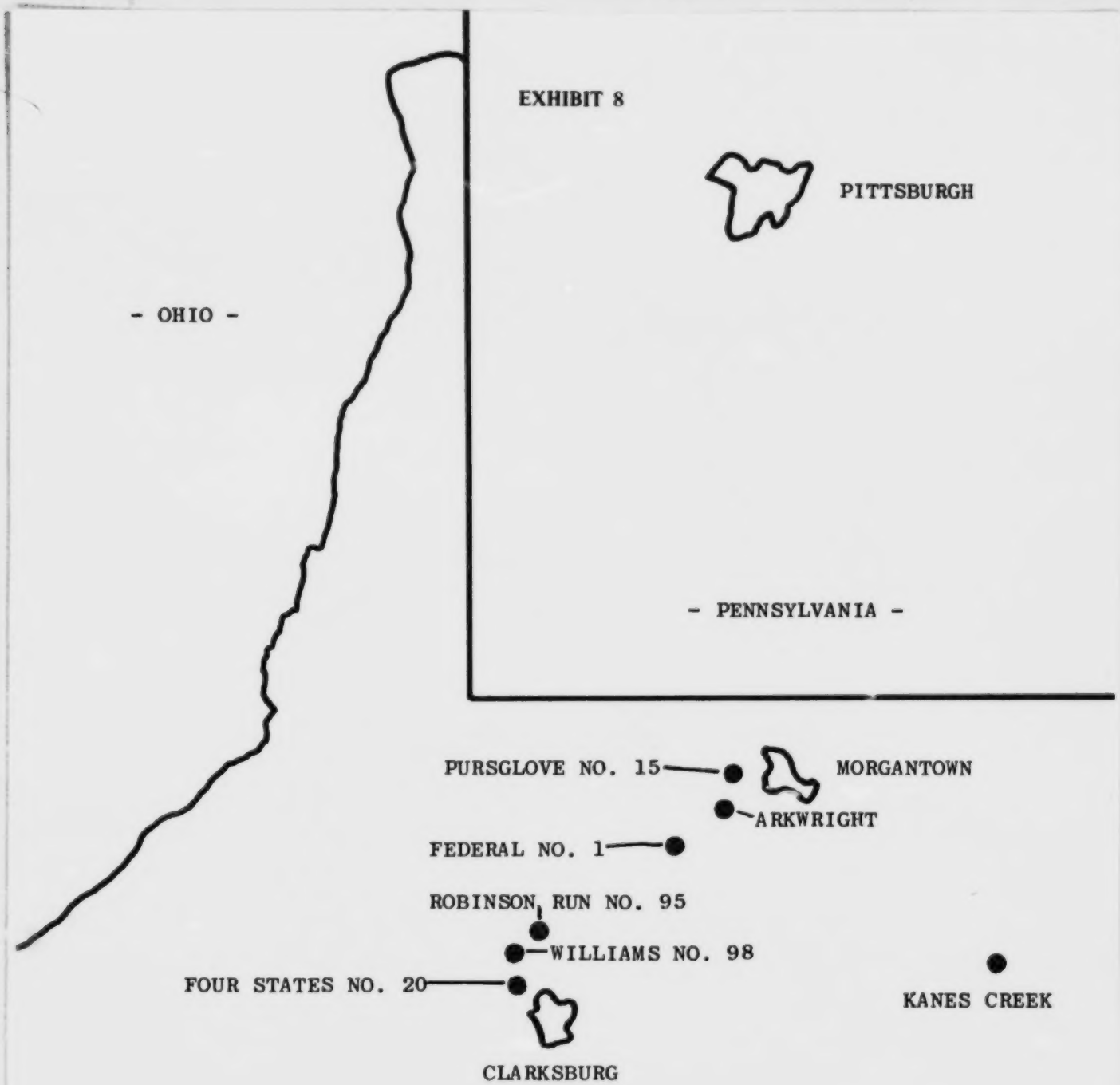
Total Flow: 28,000 gallons per day (% Treated-100%)
Method of Treatment: Neutralization with hydrated lime
Settlement

Source: "The Status of Active Deep Mines in the Monongahela River Basin", Work Document No. 46
U. S. Environmental Protection Agency
January, 1973.

CENTRAL DIVISION OF CONSOLIDATION COAL COMPANY

Cadiz, Ohio

The Central Division has 5 treatment plants for mine drainage at or near Cadiz, Ohio near Wheeling, W. Va. There are a number of settling ponds at the site of from 2 to 4 acres at a depth of 7 or 8 feet. The treated sludge (neutralized with lime) is about 10 percent solids, mostly calcium sulfate with ferrous contamination. [It was from ponds, such as these, that sludge was removed as a partial supply for a demonstration conducted at the Transpo '72 exhibit at Dulles International Airport, Washington, D.C. Exhibit 9 is a photograph of the sludge as supplied to the project site.]



UNDERGROUND MINE TREATED DISCHARGES

EXHIBIT 9

Sludge from mine drainage
treatment plant.

C. LIME SURVEY

1. Currently Available Sources

During the survey work performed by IUCS, the material found to be in the most limited supply was lime. Considering producers within a reasonable distance of proposed processing sites, only three existing operations were found to be of a size sufficient to supply hydrated lime for Poz-O-Tec processing. This is not to say, however, that a small existing operation could not be expanded to supply the increased demand in West Virginia in the future.

Some waste lime was located in the Wheeling area, but the reactivity of the material was very low. Thus this material could only be used to supplement (not replace) normal hydrated lime in the formulations considered for structural materials.

Chemical analyses of the lime from the three existing producers are presented in Exhibit 10. All are of sufficient quality and purity to be used in the production of road base materials. A sample analysis of the waste lime available is shown in Exhibit 11. The sources are located geographically on Exhibit 12.

The major concern in the area of lime supply is one of maintaining the supply over long hauling distances at an economical rate. Sample trucking rates are presented for the major producers supplying hydrated lime to various cities in West Virginia. These rates are listed in Exhibit 13.

As a rule of thumb, rail rates for distances greater than 50 miles are generally lower than truck rates. It is almost impossible to obtain quotes without intensive negotiations based on specific quantities and locations. However, in many cases, it is believed that rates which are lower than the trucking rates might be realized by this alternative mode of transportation.

EXHIBIT 10

LIME ANALYSES

(Figures in Percent)

	Mercer	Germany Valley	National Gypsum
CaO	73.63	72.74	73.30
MgO	0.61	0.68	1.23
$Ca(OH)_2$	96.07	96.09	94.10
SiO_2	0.58	0.71	1.18
Al_2O_3	0.19	0.51	0.47
Fe_2O_3	0.13	0.22	0.17
Mn	0.002	NA	0.005
LOI	23.75	25.12	23.15
Free Moisture	0.34	NA	0.20

Legend: Mercer - Mercer Lime & Stone Company, Pittsburgh, Pa.

Germany Valley - Germany Valley Limestone Co., Riverton, West Virginia

National Gypsym - National Gypsum Company, Kimballton Quarry, Giles County, Virginia

Source: IUCS Lime Producer Survey

EXHIBIT 11

TYPICAL WASTE LIME ANALYSIS
(Figures in Percent)

SiO_2	27.00
Al_2O_3	9.50
Fe_2O_3	0.55
CaO	50.32
MgO	11.00
Mn	0.02
NaCl	.01
H_2O	0.08
Loss on Ignition	0.54

SIEVE ANALYSIS

Sieve Size	% Thru
No. 60	82
No. 100	79
No. 200	69
No. 325	59

EXHIBIT 12

MAJOR LIME PRODUCERS

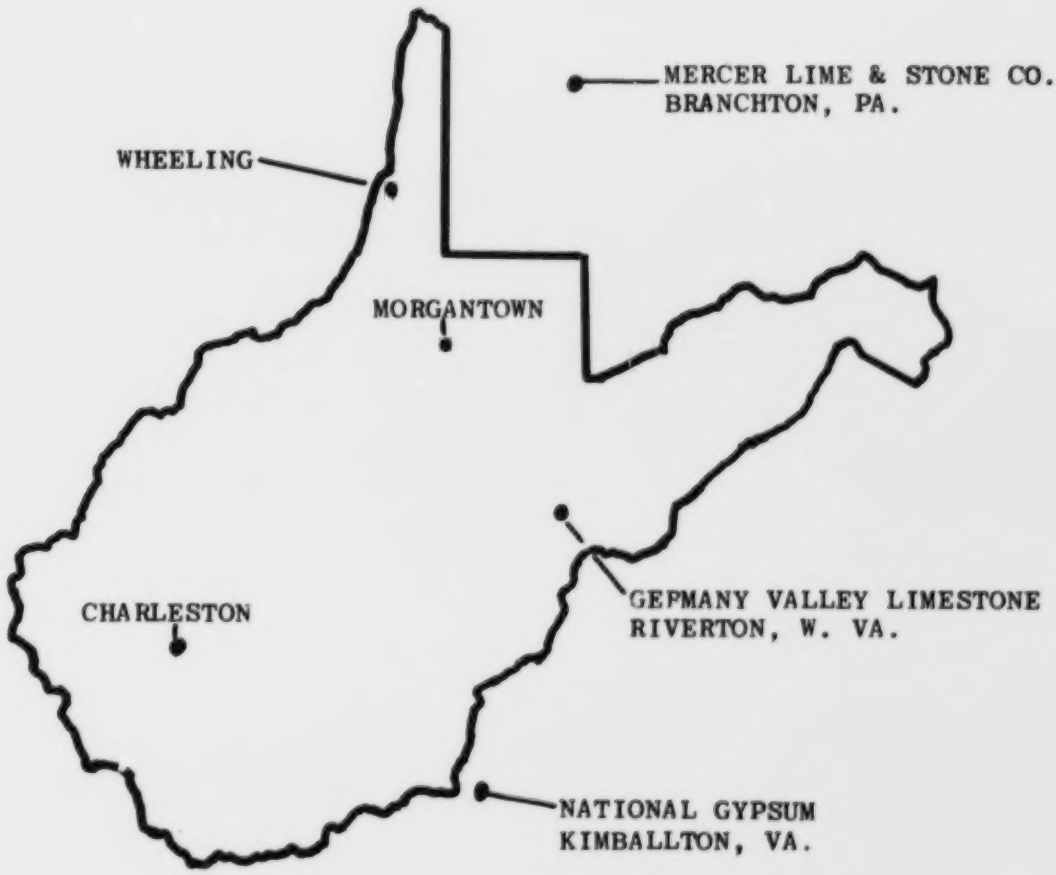


EXHIBIT 13

LIME SHIPPING RATES
(Motor Freight)

	Source					
	Mercer		Germany Valley		National Gypsum	
Plant Site	Miles	$/Ton	Miles	$/Ton	Miles	$/Ton
Wheeling	62	5.60	200	10.00	-	9.75*
Parkersburg	200	8.00	200	10.00	-	12.08*
Huntington	300	9.94	250	12.50	250	13.20
Charleston	270	9.30	200	10.00	200	9.80
Beckley	300	9.94	190	9.50	NA	NA
Morgantown	80	5.86	140	7.00	-	8.61*
Clarksburg	125	6.67	110	5.50	-	9.00*

*Supplied from Bellefonte, Pa.

Source: IUCS Lime Producer Survey

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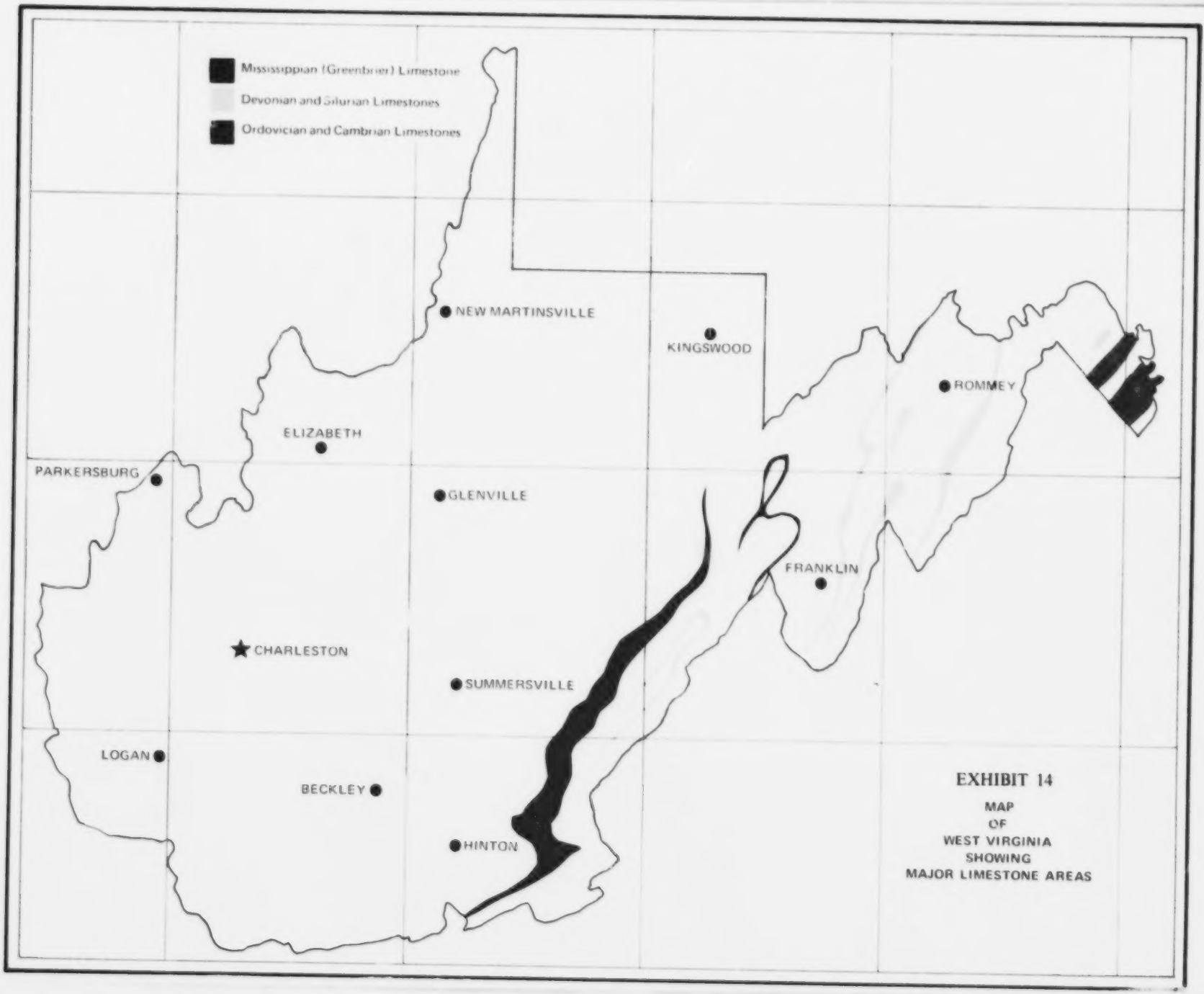


EXHIBIT 14

MAP OF WEST VIRGINIA SHOWING MAJOR LIMESTONE AREAS

2. Potentially Available Sources

In West Virginia, there are three areas that could be considered geologicaliy suited for future quarry operations (Exhibit 14). These three areas have abundant resources of commercial limestone that may be used for production of hydrated lime for numerous purposes including the stabilization of waste products and the manufacturing of portland cement. Core samples have been taken in these areas to determine stone quality, and the results of these tests are included below. In general, the tests were performed by various state geological surveys and by the Mineral Industries Experiment Station of Pennsylvania State University. Analysis are presented in Exhibits 15 through 20. Map locations of these sites are shown on Exhibits 21 and 22.

Area 1 Nestle - Snyder (Berkeley County)

The limestones in this area are part of the Stones River (St. Paul) deposits and are comprised of Cambrian and Ordovician limestones. They are less readily accessible than the other two areas mentioned later in this section, but do contain great quantities of quality limestone. Subsurface water may make the development of some of these sites difficult, but the high quality of the stone may make the operation worthwhile. As shown in the test results, some of the samples were taken on the site of a now inactive quarry at Nestle. The other samples represent the surrounding area and are rather evenly spotted. (Exhibit 15)

Area 2 Noswad - Gerstell (Mineral County)

Limestone deposits in this area, southeast of Noswad and Gerstell, are "folded" deposits resulting in larger amounts of limestone available. According to sampling tests, there are several directions in which continuous limestone is available at the surface for distances of a mile or more. Limestone in this area was quarried for many years in the now-abandoned operations of the Standard Lime and Stone Company just east of Keyser, West Virginia. Stone in this area is generally Silurian-Devonian Limestone. The following table (Exhibit 16) is a tabulation of representative samples taken from the area.

Area 3 Mississippian- (Greenbrier) Limestone

The Greenbrier limestone, from the standpoint of total quantity available, number of favorable quarry sites and vertical continuity of rock yielding high-calcium analyses, offers greater possibilities for development than the Silurian-Devonian in West Virginia. This is true despite the fact that the maximum thickness of the Greenbrier is about 400 feet, which is less than one-half of the 1,100 feet minimum for the Silurian-Devonian section. No analyses are available for this deposit.

3-1 Mace - Linwood Area (Pocanontas County)

The Mace - Linwood locality is the most favorable for production of high-calcium Greenbrier limestone in the state. The $CaCO_3$ content of the stone is consistently high, and runs about 400 feet in thickness in this vicinity. The sample analyses are presented in Exhibit 17 and are located for reference in Exhibit 21.

3-2 Yokum Knob - Osceola (Pendleton County)

Outcrops of Greenbrier limestone are abundant in this area. Transportation facilities in the general area are not good, however. If in the future these inadequacies could be overcome, a great amount of high-quality stone is available in this locality. (Exhibit 18)

3-3 Faulkner - Bowden (Randolph County)

In this area, samples show that calcium carbonate contents above 90% may be restricted to zones of limited thickness, and furthermore, the total thickness of the Greenbrier is not much more than 100 feet. There is however, suitable stone available for many purposes in this vicinity. (Exhibit 19)

3-4 Hendricks (Tucker County)

In this area, such analyses as have been made indicate an abundance of limestone meeting the requirements of cement and lime manufacture. Some of the limestone has analyzed more than 90 % $CaCO_3$ in a section 70 feet thick. (Exhibit 20)

EXHIBIT 15

Limestone Sample Analyses
- Area 1 -
(Nestle - Snyder)

Sample No.	Depth	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5
1 (Nestle)	quarry	97.05	--	.92	--	--	--
2 (Nestle)	quarry	95.98	--	1.45	--	--	--
3 (Nestle)	quarry	96.20	--	1.90	--	--	--
4 (Nestle)	quarry	96.32	.46	1.70	.11	.93	trace
5 (Nestle)	quarry	96.25	1.84	1.53	.17	.02	trace
6	surface	85.88	1.38	7.19	2.60	.86	.11
7	surface	97.05	.88	1.96	.10	.01	trace
8	surface	93.98	1.67	3.52	.22	.56	.01
9	surface	97.95	--	.72	--	--	--
10	surface	96.20	.88	.93	.11	.11	.01
11	surface	98.14	--	.80	--	--	--
12	surface	99.07	1.30	.70	.12	.01	.01
13	surface	85.47	1.90	9.71	1.04	1.90	.03
14	surface	89.90	2.64	5.17	.52	1.14	.06

EXHIBIT 16

LIMESTONE SAMPLE ANALYSES
- Area 2 (Noswad - Gerstell) -

Sample No.	Depth	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	AL_2O_3	P_2O_5
15	Surface	97.31	.46	.86	.11	--	--
16	20' Composite	95.46	1.38	3.72	.22	--	--
17	15' Composite	96.65	.88	1.25	.52	--	--

EXHIBIT 17

LIMESTONE SAMPLE ANALYSES
- Area 3 (Mace - Linwood) -

Sample No.	Depth	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	AL_2O_3	P_2O_5
18	63' Composite	93.12	2.18	2.99	1.50	1.50	--
19	20' Composite	91.51	.32	6.62	.19	.62	--
20	15' Composite	95.83	1.87	2.14	.29	--	--
21	Surface	97.54	.18	1.26	.08	.36	--
22	Surface	87.09	4.85	7.25	.42	--	--
23	40' Composite	96.41	1.36	1.48	.15	.10	--

EXHIBIT 18

Limestone Sample Analyses
- Area 3 (Yokum Knob - Osceola) -

Sample No.	Depth	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5
24	100' composite	93.34	1.30	4.53	.22	.50	--
25	110' composite	86.48	5.38	6.82	.40	.40	--

EXHIBIT 19

Limestone Sample Analyses
- Area 3 (Faulkner - Bowden) -

Sample No.	Depth	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5
26	6' composite	96.21	.87	2.02	.37		--
26	70' composite	82.97	3.94	12.01	1.17		--
27	15' composite	91.36	2.07	5.62	.66		--
28	20' composite	86.81	3.32	8.93	1.02		--

EXHIBIT 20

Limestone Sample Analyses
- Area 3 - (Hendricks) -

Sample No.	Depth	$CaCO_3$	$MgCO_3$	SiO_2	Fe_2O_3	Al_2O_3	P_2O_5
29	70' composite	91.23	1.30	2.02	--	--	--

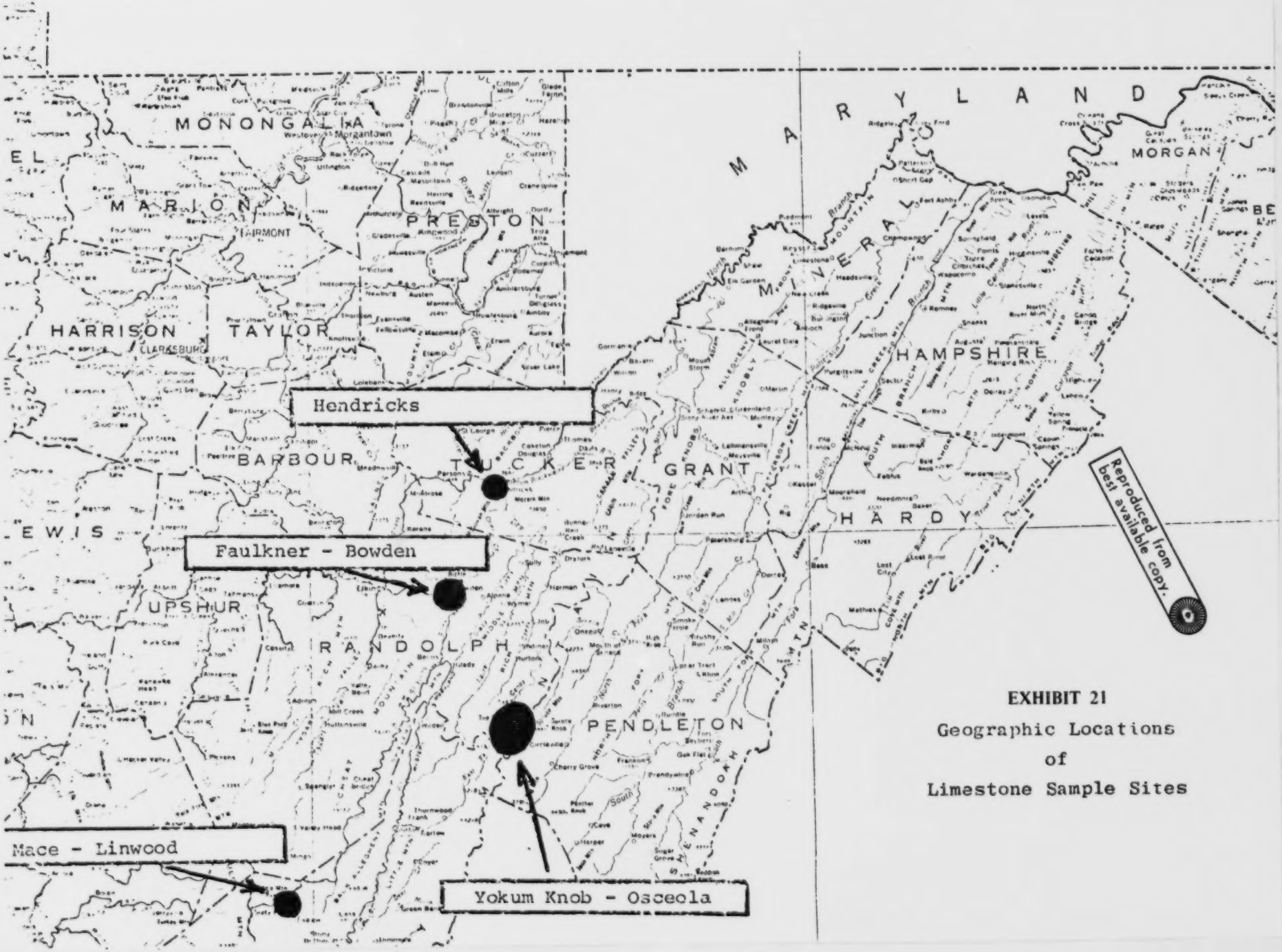


EXHIBIT 21

Geographic Locations

of

Limestone Sample Sites

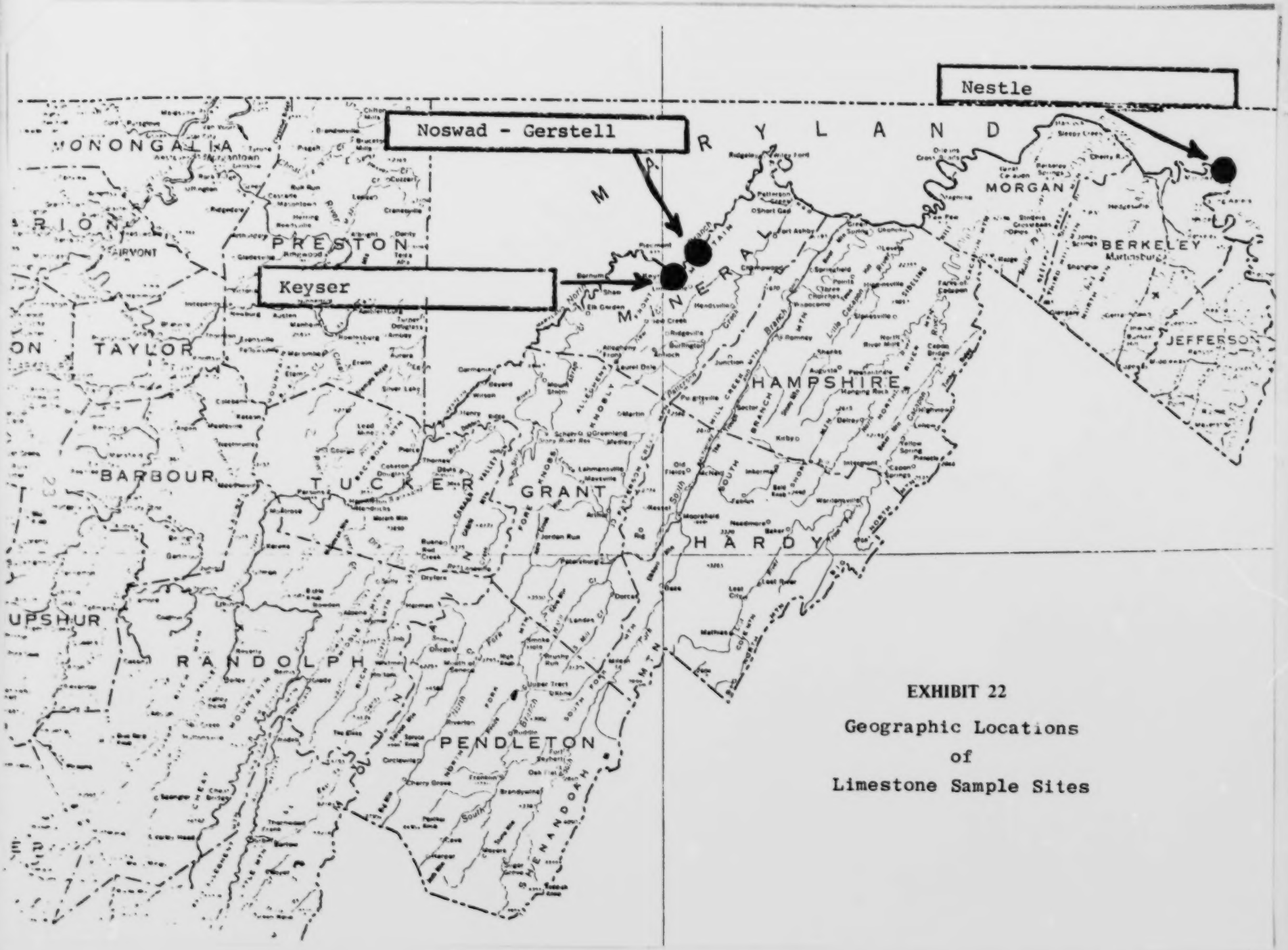


EXHIBIT 22

Geographic Locations
of
Limestone Sample Sites

D. MINE REFUSE SURVEY

Awareness of the vast problems associated with coal refuse in the state of West Virginia has led to much speculation and research on methods of disposal for this material. Some potential plans for disposal include backfilling of voids left by strip and underground mines and general use as a landfill type material for improvement of surface contours. However, these processes would require enormous sums of money when one considers the machinery and transportation cost necessary to move such a large amount of material. A more attractive solution to the refuse disposal problem would be the utilization of this waste as a raw material for the production of marketable products, such as a source of cheap aggregate for highway construction.

Although research on this particular use of mine refuse is far from complete, initial tests have shown that this material can be incorporated into a Poz-O-Tec™ matrix as a substitute for natural aggregate. Since these spoil banks are sometimes structurally hazardous in themselves and can leach sulfuric acid from reaction of the pyrites contained in the refuse with water, elimination of this mine refuse by incorporation into a Poz-O-Tec™ matrix would prove to be of manifold benefit.

Appendix A - At the end of this report shows the location and size of mine refuse banks that exist in the State of West Virginia, giving some idea of the size and urgency of the problem. The tables are basically divided by district, but are subdivided into the following categories: 1) burning bank, 2) water impoundment, and 3) dry dump. "Burning bank" refers to those piles that are actually smouldering, "water impoundment" refers to those banks that have trapped or "soaked up" water, and "dry dump" are simply raw or unburnt spoil.

E. CURRENT MATERIALS SURVEY

Exhibits 23, 24 and 25 summarize the production and local availability of some of the major currently-used highway construction materials (cement, crushed stone, and sand and gravel) within the State of West Virginia. The exhibits show the critical shortages of these conventional materials in certain parts of the State. These deficiencies could be alleviated by the use of road construction materials formulated from waste products already available in great quantities in West Virginia. Because of shortages within the state, in some instances, certain materials (especially crushed stone) must be trucked or barged from adjacent areas in order to obtain sufficient quantities of materials to meet strict specifications. This, of course, represents a substantial flow of money out of the State of West Virginia which could be curtailed by replacing some of these imported materials with locally manufactured synthetic structural materials.

Also included in this section are summary sheets of the average unit prices paid by the State of West Virginia for its current highway construction materials. Tables are included for aggregate (Exhibit 26) and for landfill (Exhibit 27). Definitions for the various categories of materials listed in these exhibits can be found in Appendix B.

EXHIBIT 23

CRUSHED STONE IN WEST VIRGINIA

The crushed stone available in West Virginia varies greatly in quality. The limestone and sandstone available in the Morgantown-Clarksburg area is relatively inexpensive but of a poor quality, and cannot always be used for construction purposes. The stone from the eastern regions of the state is of a higher quality, but transportation costs from Berkeley County into Charleston or Morgantown-Clarksburg areas are high. Higher quality stone and slags are also brought into the Charleston area by barge from surrounding states, but again the loading and transportation costs are high. Below is a summary of results from the IUCS survey on crushed stone in West Virginia.

I. MAJOR AREAS OF PRODUCTION (Crushed Limestone and Sandstone)

Berkeley County

Preston-Monongalia Counties

Jefferson County

Greenbrier County

2. PRODUCTION (Crushed Limestone and Sandstone) 1972

A. OVERALL TOTALS **7,300,000 Tons Limestone**

2,400,000 Tons Sandstone

B. USAGE:

Of the 7,300,000 tons of crushed limestone produced, only 15% could be used for dense grade road base because of the marginal quality of much of this stone. Other specified uses accounted for the following amounts:

10% Concrete Aggregate

8% Bituminous Aggregate

4% Surface Treatment

6% Unspecified Aggregate Road Stone

It can only be assumed that the remainder of the stone (57%) was not of sufficient quality for specified construction use.

C. IMPORTED STONE

Of the total limestone produced in West Virginia in 1972* (7,300,000 tons) only 15% could be used by the West Virginia Department of Highways. DOH figures for the same calendar year show a total purchase of 1,480,157 tons of specified aggregate road stone. It can be assumed that the difference between these figures is the net tonnage brought in from surrounding states--approximately 385,000 tons per year. Assuming a cost of $10.00 per cubic yard (or $6.75 per ton), this importation costs the State of West Virginia in excess of $2,500,000 per year.

* Minerals Yearbook
IUCS Materials Survey
West Virginia DOH

EXHIBIT 24

SAND AND GRAVEL IN WEST VIRGINIA

1. MAJOR AREAS OF PRODUCTION (Sand and Gravel)

Dredging from Ohio River from Steubenville to Huntington

West from Ohio River to Columbus, Ohio

2. PRODUCTION (Sand and Gravel) 1970

A. OVERALL TOTALS: **4,396,000 Tons Sand and Gravel**
2,954,000 Tons Sand Only

B. USAGE: **425,000 Tons Gravel for Paving Use**
343,000 Tons Sand for Paving Use

EXHIBIT 25

CEMENT IN WEST VIRGINIA

1. **MAJOR AREA OF PRODUCTION**

   Berkeley County

   PRODUCTION* (Estimated Due to Company Confidential Data)

   A. **OVERALL TOTALS:** 2,500,000 bbls. Portland Type I
   350,000 bbls. "High-Early" type

   B. **END USES:** Ready-Mix Concrete
   Concrete Products
   Building & Highway Construction

* Capital Cement Co., Division of Martin Marietta Corp., at Martinsburg, Berkeley Co., is sole producer.

Source: Minerals Yearbook and IUCS Materials Survey

EXHIBIT 26

AGGREGATE UNIT
PRICES
- 1972 -

	CAT. "A"	INTERSTATE	APD	ABC & STATE
Class 1 Agg. Base Course (yd.^{3})	$10.46	$10.91	$11.63	$11.38
Class 2 Agg. Base Course (yd.^{3})	-	$10.79	$10.07	$11.65
Class 3 Agg. Base Course (yd.^{3})	-	$12.72	$11.44	$10.98
Grade 1 Subbase Aggregate (yd.^{3})	-	$10.80	-	-
Grade 2 Subbase Aggregate (yd.^{3})	$ 6.12	-	-	$ 6.47
Class 7 Agg. Stone (A) (Base) (ton)	$ 8.98	-	-	$10.16

EXHIBIT 27

WEST VIRGINIA DEPARTMENT OF HIGHWAYS
AVERAGE UNIT BID PRICES
- 1972 -

A. UNCLASSIFIED BORROW EXCAVATION

Project Type	Amount Used	Price Range	Avg. Price Paid
APD Projects	496,837 yds.^{3}	$1.10 - 1.10	$1.10
Interstate	201,878 yds.^{3}	$1.25 - 6.00	$2.41
ABC & State	41,721 yds.^{3}	$1.80 -10.00	$2.70
Category "A"	17,253 yds.^{3}	$3.00 - 7.00	$4.10

B. SELECT BORROW EXCAVATION

Project Type	Amount Used	Price Range	Avg. Price Paid
APD Projects	-	-	-
Interstate	26,373 yds.^{3}	$8.50 - 8.50	$8.50
ABC & State	28,426 yds.^{3}	$0.30 - 10.00	-
Category "A"	8,395 yds.^{3}	-	$6.95

F. PLANNED ROADS AND HIGHWAYS SURVEY

In response to the specific request by the Appalachian Regional Commission, IUCS surveyed planned road work in West Virginia using inputs from the West Virginia Department of Highways, National Highway Needs Studies, and detailed data developed by private firms for the State of West Virginia. Exhibit 28 summarizes the general highway construction needs in West Virginia for the near future. While forecasted costs are presented for the planned highway construction, these figures should not be converted to average costs per mile of conventional road because of the special considerations and other variances of individual projects. The data are included, however, to give a general idea of the amount and overall cost of roadwork which is planned within the State. A more detailed treatment of current costs and comparisons with synthetic construction materials is discussed in a later section of this report.

EXHIBIT 28

WEST VIRGINIA HIGHWAY NEEDS

-Summary-

A. Population Group - HUNTINGTON-ASHLAND

	Miles	Cost ($)
- PRINCIPAL ARTERIALS		
New Locations	2	24,668,000
Exist. Loc. Maj. Const.	9	9,895,000
- MINOR ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	7	3,366,000
- COLLECTORS		
New Locations	0	0
Exist. Loc. Maj. Const.	13	5,907,000

B. Population Group - STEUBENVILLE-WEIRTON

- PRINCIPAL ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	0	4,800,000
- MINOR ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	3	1,441,000
- COLLECTORS		
New Locations	0	0
Exist. Loc. Maj. Const.	10	4,741,000

C. Population Group - WHEELING

- PRINCIPAL ARTERIALS		
New Locations	7	37,232,000
Exist. Loc. Maj. Const.	19	22,626,000
- MINOR ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	26	28,181,000

	Miles	Cost ($)
- COLLECTORS		
New Locations	0	0
Exist. Loc. Maj. Const.	32	17,289,000

D. Population Group - CHARLESTON

- PRINCIPAL ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	23	63,534,000
- MINOR ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	48	72,964,000
- COLLECTORS		
New Locations	0	0
Exist. Loc. Maj. Const.	92	57,522,000

E. Population Group - PARKERSBURG

- PRINCIPAL ARTERIALS		
New Locations	7	12,052,000
Exist Loc. Maj. Const.	4	11,611,000
- MINOR ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	4	1,969,000
- COLLECTORS		
New Locations	0	0
Exist. Loc. Maj. Const.	14	6,098,000

	Miles	Cost ($)
F. Population Group - CUMBERLAND (Ridgeley)		
- PRINCIPAL ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	0	0
- MINOR ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	2	724,000
- COLLECTORS		
New Locations	0	0
Exist. Loc. Maj. Const.	2	775,000
G. Population Group - MORGANTOWN-CLARKSBURG		
- PRINCIPAL ARTERIALS		
New Locations	3	18,341,000
Exist. Loc. Maj. Const.	18	20,626,000
- MINOR ARTERIALS		
New Locations	0	0
Exist. Loc. Maj. Const.	4	1,522,000
- COLLECTORS		
New Locations	0	0
Exist. Loc. Maj. Const.	12	7,286,000

H. Nontechnical Explanation of Terms

Population Group - a "population center" usually named by the largest metropolitan area within its boundaries.

Principal Arterials - heavily traveled, high speed, highly engineered highways designed for long distance connection between the population groups. These require the best performance characteristics possible.

Minor Arterials - highways generally designed for lower volume traffic than a principal arterial, but still of a class necessitating substantial engineering effort and careful control of construction material quality.

Collectors - local roads, used as feeders of local traffic onto the minor or principal arterials. Design should be adequate to keep maintenance to a reasonable level.

New Locations - construction starting on a previously undeveloped area. Usually involves grading and all preparatory work.

Existing Location Major Construction - major addition or improvement to an already developed site; e.g., addition of lanes to an already existing highway and/or relocation of sections.

Source: National Highway Functional Classification and Needs Study. Cost and Mileage Summary.

IV. ECONOMICS

A. MANIPULATION

In this section, the data gathered in the survey sections of this report will be analyzed to determine the following:

1) The optimum sites for production of synthetic road base material,

2) the estimated unit cost of production of the material, and

3) the cost benefits of using lime-fly ash-sludge formulations vs. the present methods used in West Virginia.

All analysis has been based on the production of lime-fly ash-sludge road base material in and around the following metropolitan areas: Huntington, Weirton, Wheeling, Charleston, Parkersburg, Morgantown, and Clarksburg.

It is unrealistic to base an economic exercise on the replacement of all current materials with synthetic structural materials. The economic comparisons that follow, therefore, have been kept as free as possible from the factors of supply and demand and are examined solely on a ton vs. ton basis.

The following analyses assume a road base depth of 12 inches for both natural and synthetic materials. This is a conservative estimate and will be modified upon examination of any test strip under actual loading conditions. Using this depth figure, each mile of road base (2 lanes, each lane 12 feet wide) requires approximately 4700 tons of lime-fly ash-sludge materials.

B. OPTIMAL PLANT SITES

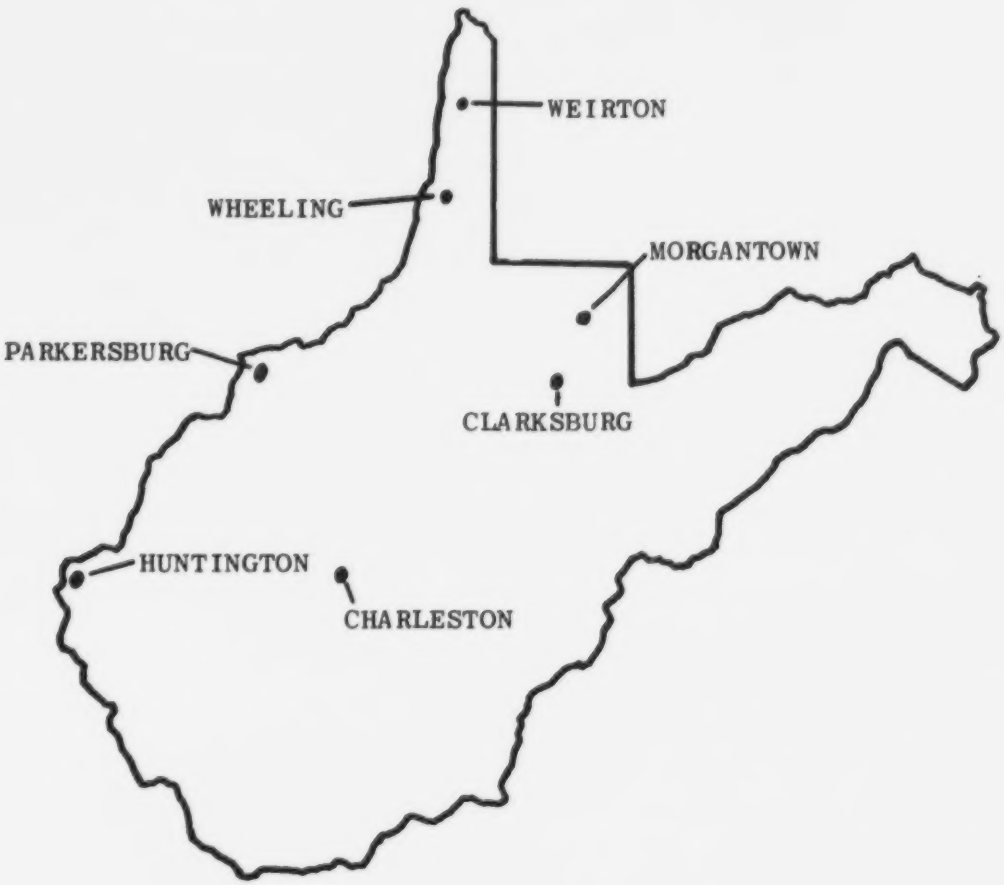
The optimal location of stabilized road base plants in the West Virginia area is based on the availability of the lime, fly ash, and sludge sources. Also generally considered in all cases was the availability of sufficient equipment for production and placement, and the proximity of necessary road work to be done.

The economics of the stabilization process depends heavily on the availability of input materials and transportation costs. Bearing in mind these factors and their relative impact, the best locations for Poz-O-Tec™ plants are near the following metropolitan areas: Charleston, Huntington, Parkersburg, Wheeling-Weirton, and Morgantown-Clarksburg. The methodology used to develop these sites minimized total transportation cost of materials assuming the freight costs of outbound product to be comparable for each site.

As shown in Exhibit 29, Plant 1 services the Charleston Area; Plant 2 the Huntington Area; Plant 3 services both Wheeling and Weirton; Plant 4 services Parkersburg, and Plant 5 services both Morgantown and Clarksburg. These plant sites are approximate and would change if road construction (or any other use of the material) shifted demand to another locale. Exhibit 30 shows the input sources that could tentatively be used for each plant and its projected output tonnages of Poz-O-Tec™ materials.

EXHIBIT 29

PROPOSED OPTIMAL PLANT SITES



PROPOSED MAXIMUM ANNUAL OUTPUT TONNAGES:*

1.	Charleston	815,000
2.	Huntington	165,000
3.	Weirton-Wheeling	485,000
4.	Parkersburg	150,000
5.	Morgantown-Clarksburg	500,000

*Based on projected road base requirements in area.

EXHIBIT 30

OPTIMUM PLANT LOCATIONS

PROCESSING SITE	POSSIBLE INPUT SOURCES	OUTPUT TONNAGES* PER YEAR
Charleston	(F.A.) John Amos Stn. (F.A.) Philip Sporn Stn. (F.A.) Kanawha Stn (Lime) Nat'l. Gypsum (Sulf.) Chemical Wastes (Sulf.) Mine Treatment	815,000 (Max.)
Huntington	(F.A.) Big Sandy Stn. (Lime) Germany Valley (Sulf.) Chemical Wastes (Sulf.) Mine Treatment	165,000
Weirton-Wheeling	(F.A.) Cardinal Stn. (F.A.) Mitchell Stn. (F.A.) Burger Stn. (Lime) Mercer Lime & Stone (Sulf.) Chemical Wastes (Sulf.) Mine Treatment	485,000
Parkersburg	(F.A.) Muskingum (F.A.) Phillip Sporn Stn. (Lime) Mercer Lime & Stone (Sulf.) Chemical Wastes (Sulf.) Mine Treatment	150,000
Morgantown-Clarksburg	(F.A.) Albright Stn. (F.A.) Hatfield Stn. (F.A.) Fort Martin Stn. (F.A.) Harrison Stn. (Lime) Mercer Lime & Stone (Sulf.) Mine Treatment	500,000

*Based on projected road base requirements in area.

C. PRICES FOR MONOLITHIC STRUCTURAL MATERIAL

The estimated price, f.o.b. the various production sites, is illustrated in Exhibit 31. Unlike many industrial processes, the f.o.b. price at various sites tends to rise as the quantity of road base produced increases. This is caused by the fact that as more material is produced, it requires more fly ash, and other materials, which have to be trucked to the site from greater distances as the closest supplies are exhausted. Thus the normal reduction in cost per ton of plant operations as output increases is more than counteracted by increase in transportation costs of materials

The values given in Exhibit 31 were derived on the basis of the cost of hydrated lime of $18.00 per ton (f.o.b.) which was the average price at the time of the survey. No value has been included for the cost of either the sludge or the fly ash since these are primarily being discharged to wasteland. It should be recognized, however, that there may be situations where costs can develop to handle these waste materials. Depending on which organization undertakes to assume this responsibility, a charge or a credit could be applied to this cost estimate. Information which was received from a local producer of fly ash road base has provided the additional operating cost and other cost estimates that have been included to establish the values given in the last column.

As indicated, the increase in cost of the higher production rate is a reflection of the added cost of hauling of fly ash and other materials. Exhibits 5 and 13 were used as a basis for these trucking charges. The formulation that was used in making the estimates was based on compositions that proved to work satisfactorily at the Transpo 72 project at Dulles Airport. The lime content (which is the expensive ingredient) was therefore established at 2½ percent of the weight of the final mixture.

D PRICE COMPARISONS

Initial investigation indicates that the cost per ton of crushed stone road base, F.O.B. the major metropolitan areas, ranges from $4.00 - $6.50 per ton ($4.85 - $7.90 per cubic yard) as a function of the quality of the material and the location of the metropolitan area. The cost of Poz-O-Tec™ road base also varies by location as indicated in Exhibit 31. Because of the fact that the suggested production sites are located near the demand areas, the price would not increase significantly due to distance from the "availability areas", as would be the case with other road base materials.

Placement costs of Poz-O-Tec™, depending on site preparation, size of project, etc., is assumed to be about one dollar per ton, which is approximately equivalent to other conventional road bases. Cost per mile calculations, then, can be estimated once the specifications for base thickness and width have been established.

The following comparison (Exhibit 32) is based on a base width of 24 feet, and a depth of one foot for stone and Poz-O-Tec™. As mentioned earlier, the depth requirement for Poz-O-Tec™ will most probably decrease when design parameters are more strictly determined.

EXHIBIT 31

PRELIMINARY ESTIMATED PRICES AT VARIOUS LOCATIONS
(Using 1972 Costs)

Site	Production Level (Tons Per Year)	Avg. Cost Per Ton ($ Per Ton F.O.B.)
Weirton-Wheeling	250,000	$2.25
	485,000	3.25
Charleston	320,000	3.40
	815,000	3.90
Morgantown-Clarksburg	250,000	3.50
	500,000	3.85
Parkersburg	50,000	4.65
	150,000	4.80
Huntington	50,000	4.90
	165,000	5.13

EXHIBIT 32

ROAD BASE ECONOMIC COMPARISONS

CLASS 1 - AGGREGATE BASE COURSE

	Conventional Material	Poz-O-Tec™
avg. price per ton, f.o.b.	$5.00- 6.50	$3.00-5.00
avg. price per cubic yard[1], f.o.b.	$9.45-12.25	$3.75-6.20
tons per mile of road base[2]	8870	5830
cost per mile of road base	$51,000.	$23,320.

CLASS 2 - AGGREGATE BASE COURSE

avg. price per ton, f.o.b.	$4.50- 6.00	$3.00-5.00
avg. price per cubic yard[1], f.o.b.	$7.55-11.35	$3.75-6.20
tons per mile of road base[2]	8870	5830
cost per mile of road base	$46,570.	$23,320.

CLASS 3 - AGGREGATE BASE COURSE

avg. price per ton, f.o.b.	$4.00- 6.00	$3.00-5.00
avg. price per cubic yard[1], f.o.b.	$7.55-11.35	$3.75-6.20
tons per mile of road base[2]	8870	5830
cost per mile of road base	$44,350.	$23,320.

[1] Compacted density stone at 140 lbs/ft^3 ; Poz-O-Tec™ at 92 lbs/ft^3

[2] Assume 24 foot width, 1 foot depth

E. LANDFILL & MINE RECLAMATION OPPORTUNITIES

As mentioned earlier in this report, there are tremendous needs in the State of West Virginia for "fill" materials capable of alleviating the problems of unreclaimed stripping areas, deep mine subsidence, and unstable road shoulders. As part of the survey work performed by IUCS for this report, the prices and amounts of borrow excavation, select and unclassified, were determined. The tabulation of this data is presented in Exhibit 27. As can be seen from this data, the average price per cubic yard of this material is low. What the data does not show, however, is the need for ever-increasing amounts of this type of material for reclamation and stabilization projects like those mentioned above. Accompanying this increasing demand, unfortunately, is the fact that good fill materials are becoming scarce. Borrow excavations are naturally limited and will never be the final answer to the demand for these restoration and reclamation materials.

It is the conclusion of IUCS that the use of lime-fly ash-sludge compositions may hold the answer to a significant part of the problem. In the future, the advent of power plant scrubber operations will increase the amounts of fly ash and sludge materials. Considering the fact that in these circumstances the sources of raw materials are local and of significant quantity, the economics of Poz-O-Tec™ processing will permit the erection and operation of a conversion facility on or adjacent to any coal-burning power plant. The decrease in transportation costs should then permit the production of a landfill-type material that would be inexpensive and quite suitable for use in the problem areas where it is required.

V. DEVELOPMENT OF DESIGN CRITERIA FOR PAVEMENTS WITH LIME-FLY ASH-SULFATE MIXTURES

A. INTRODUCTION

Development of technology and design criteria to support the use of new paving materials is a multifaceted problem. In times past when our society and economy moved at a slower pace, step by step approaches could be undertaken which would permit the logical development of technology and design criteria to support a design procedure. This is not possible under circumstances which exist today, so procedures must be followed which will decrease the time between conception and implementation to an acceptable interval.

The minimum steps which are necessary to develop design criteria for new paving materials are:

1) determine the significant engineering properties of the materials through laboratory studies;

2) extrapolate tentative pavement design criteria and design parameters by comparison of the significant engineering properties with the properties of other paving materials in current use;

3) validate the tentative criteria through demonstration pavements under service conditions;

4) develop a monitoring and feedback program to evaluate the long range reliability and performance of the pavements in service.

The above program permits provisional utilization of new materials with a relatively short lead time, with a minimum or risk to the using agency. A program as outlined above is proposed to develop technology and design criteria for pavements using lime-fly ash-sulfate (LFS) mixtures.

B. DEVELOPMENT OF ENGINEERING PROPERTIES

A significant effort was expended to evaluate the engineering properties of LFS mixtures for the demonstration pavements at the Dulles International Airport for Transpo '72. These data show that LFS mixtures have the potential to make quality paving materials, but that the specific properties of the cured mixtures are a function of the mix components. Some examples of typical data developed in this study are shown in Exhibit 33. A study of the data in this table reveals some of the mixtures have adequate strength and durability, while others have adequate strength but marginal durability. Other mixtures evaluated in this same study but not shown here had properties which varied from excellent strength and durability to inadequate strength and durability and all combinations between.

Exhibit 34 is a photograph of one project (Transpo '72) showing the processing plant for production of a lime-fly ash-sludge mixture. Exhibit 35 shows a partial view of the completed project.

The data developed for the Transpo '72 study clearly shows that the LFS mixtures have the potential to make high quality paving materials. Until adequate data are available, however, to predict the properties of the mixtures from properties of its components, it will be necessary to evaluate each mixture separately and measure its significant engineering properties.

C. PAVEMENT DESIGN CRITERIA

Preliminary design criteria for new paving materials can be established from design criteria for other paving materials in use with comparable engineering properties. The materials in current use with properties similar to those of the LFS mixtures are the lime-fly ash-aggregate (LFA) mixtures, currently produced under the trade name, "Poz-O-Pac®" Many of the identical reaction products which are formed in the LFA mixtures are also present in LFS mixtures. Patterns for development for strength, durability and dimensional stability are similar for the LFA and LFS mixtures. Thus, there is reason to believe that with the background experience with the LFA mixtures as a basis, satisfactory design criteria can be developed for LFS mixtures which can be verified through use of the proposed demonstration pavements.

While LFA materials are relatively new as paving materials go, there are extensive research data and service records available to substantiate the performance of these materials (see Appendix C). Some pavements with LFA mixtures have been in service for nearly 20 years. While there have been some failures, most of these pavements have given outstanding performance. It is through study of these pavements with both success and failures that the requisite design criteria have evolved. Use of these materials has continued to expand over the years, indicating a growing acceptance of LFA mixtures as a paving material. These mixtures have been approved for use in a number of states, by the Federal Highway Administration (FHWA), and other agencies.

The FHWA has recently circularized a notice (N 5080.4, January 17, 1974) to its regional offices which advocates approval of the use of fly ash in lieu of cement and fly ash with lime for stabilization of soils and road base materials. Also of interest is the Federal Aviation Administration Specification 5370 which now includes a Section 305.1.1 that covers the use of LFA mixtures in the construction of base courses for air fields and for related purposes.

Design criteria for pavements with LFA mixtures vary with the agency or highway department. Space does not permit a detailed discussion of the various approaches in use, but it is significant to note that those agencies that used the design procedure indicated in the AASHO Interim Guide usually assign a coefficient value approximately twice that of crushed stone. Thus, each inch of thickness of LFA material is as effective as two inches of crushed stone in providing pavement performance. Other equivalencies and design parameters can be established from current practice. These parameters and equivalency values can be used as a guide to establish comparable design parameters for LFS mixtures for design of demonstration pavements.

EXHIBIT 33

STRENGTH AND DURABILITY TESTS
OF LFS MIXTURE USED AT TRANSPO 72

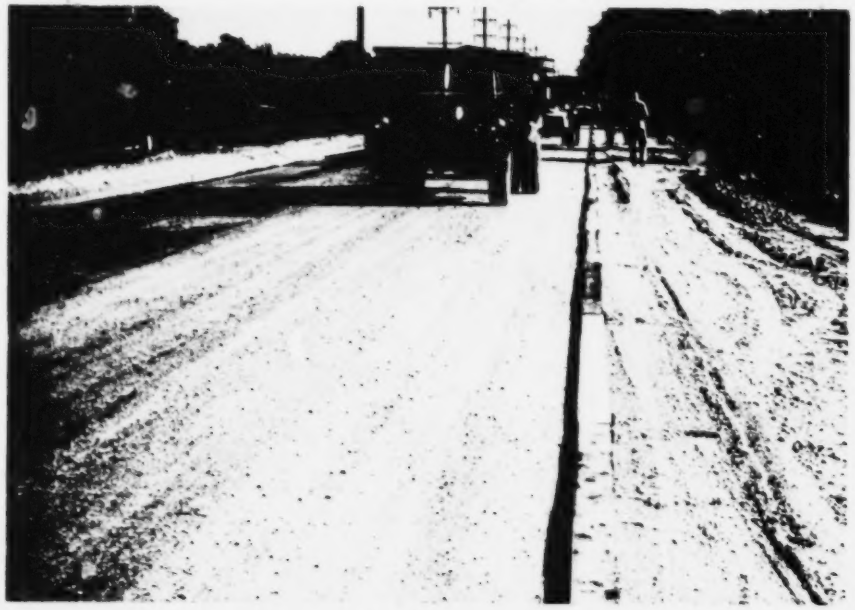
Mix No.	Compressive Strength (psi)		CBR (%)	Weight Loss After 12 Freeze/Thaw Cycles (%)
	14 Days at 100°F	28 Days at 75°F	7 Days at 75°F	
HFB-2	732	621	543	<14
HFB-5	630	570	700	9
HFB-6	458	472	460	> 1
HFB-7	772	860	580	3
HFB-8	739	770	644	4
MDB-4	756	560	510	<14
MDB-5	725	557	506	7
SSB-4	925	477	161	<14
SSB-8	963	676	151	<14

EXHIBIT 34

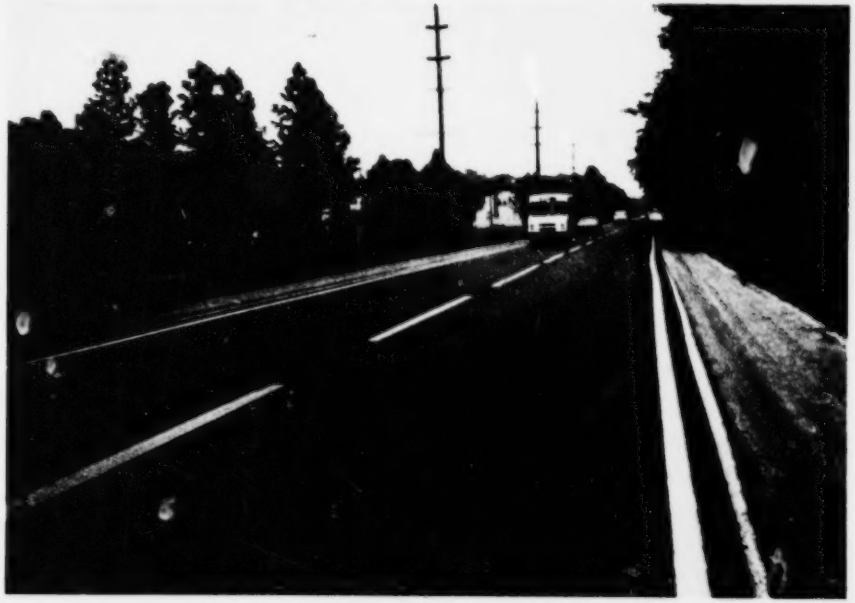
Poz-O-Tec™ processing plant at Transpo '72,
Dulles International Airport, Washington, D. C.

EXHIBIT 35

Partial view of parking lot area at
Transpo '72, Dulles International Airport



POZ-O-PAC® PLACED READY FOR WEARING COURSE, 1956
SALEM CO., NEW JERSEY



SAME ROAD, SUMMER, 1974

COMPLETED ROADWAY 1965
SUSQUEHANNA ROAD, MONTGOMERY CO., PA.

SAME ROAD, SUMMER, 1974

D. DEMONSTRATION PAVEMENTS

Purposes of the demonstration pavements are:

1) to provide a medium for demonstrating the potential of the paving material under simulated service conditions;

2) to establish limiting conditions for using the material;

3) to validate the proposed or to provide a basis for changing the design criteria including the assignment of equivalency coefficients and other design parameters;

4) to provide information necessary for the development of realistic construction specifications.

To be of value, it is necessary that the demonstration pavements be designed to provide preliminary answers as soon as possible, with more detailed data being collected as the pavement matures.

E. DESIGN OF DEMONSTRATION PAVEMENTS

The ultimate validation of a paving material is its performance in service. Pavement performance is controlled by three primary properties of paving materials. These are:

1) Durability

2) Strength

3) Dimensional Stability

For purposes of this discussion durability is defined as the ability of a material to resist change under the environmental conditions in service. All materials must meet minimum durability criteria to give satisfactory performance. These criteria should be closely tied to the actual conditions expected to exist in the material in service. It is unrealistic to adopt arbitrary criteria which are unrelated to actual service conditions, for purposes of documenting actual performance data on a material. Thus, the environmental conditions at the site must be evaluated and the durability of the material related to these conditions.

Strength has long been considered a criteria for evaluating the quality of paving materials. Many different test procedures have been developed to measure strength characteristics of paving materials. Results from these tests can often be correlated with other test results, and the specific tests selected are usually related to the design procedure used. The strength characteristics of the materials used in these demonstration pavements will be evaluated through tests which will provide the necessary information to be applied with the West Virginia Department of Highways design procedures. This will require, among others, test results using the cohesiometer and stabilometer to establish the gravel equivalency of the material.

All paving materials shrink and expand with changes in temperature and moisture. If these changes are great enough, to the ductility of the material low enough, the pavements will crack. All paving materials in use today do crack as a direct result of these dimensional changes; some more so than others. One purpose of the demonstration pavements is to determine the dimensional stability of the material under service conditions with its cracking tendency, and if cracking does occur, what are the effects of these cracks on the short and long term performance of the pavement system.

Based on the three factors discussed above, it is proposed that the demonstration pavements be constructed with varying thicknesses of base layers composed of a LFS mixture and a surface of asphalt concrete, with some median thickness designed in accordance with the West Virginia Department of Highways design procedure using preliminary values for gravel equivalencies of the material. For optimum value, the range of pavement thicknesses selected should be such that at least one short time span (say between 6 months and 2 years)[1]. The remaining pavements should be designed to last for a period between 2 years and the normal design life or longer.

[1]It is noted that there are serious objections to designing even demonstration pavements which fail after a few years of service. While early failure is not absolutely necessary for the success of the demonstration, it is highly desirable as it will provide much needed information on limits to be assigned in the design process.

Variations in thickness of base and surface layers should be provided to determine the effect of the thickness of these layers on durability and dimensional stability of the LFS base material.

Selection of the actual thicknesses for use in the demonstration pavements will be made when data on the subgrade conditions, anticipated traffic, and strength characteristics of the lime, fly ash and sludge mixtures to be tested are known. The actual pavement thicknesses will be selected in consultation with engineers of the West Virginia Department of Highways.

Length of each demonstration section should be great enough to permit construction with normal construction practices and equipment (probably 300-400 feet minimum length). Such lengths are adequate to evaluate the performance trends of the pavement sections.

Because of the number of potential variables which could be incorporated into the demonstration pavements, (thickness, mix designs, density, drainage, etc.) a complete experimental factorial is impractical. Rather it is recommended that the demonstration be limited to 4 or 5 different pavement sections involving variable paving thicknesses with one or two of the most promising lime, fly ash, sludge mixtures. All pavements should be compacted to the greatest possible density consistent with construction practice and economics.

F. AFFILIATED TESTING PROGRAM

For maximum benefit from any demonstration pavement it is necessary that the material characteristics and construction practices be carefully documented before and during construction. Thus, it is necessary that a comprehensive laboratory and field testing program be initiated in conjunction with this demonstration project. When deciding whether or not a specific test should be conducted, it is best to keep in mind that any data collected can be filed and not used; but after the project is complete, data that was not collected can never be obtained with any degree of certainty. Thus it is better to err in the direction of collecting excess test data than too little data. A recommended program for laboratory and quality control testings follows.

LABORATORY TEST PROGRAM

Subgrade Soil

Minimum Program

1. Stabilometer (R Valve)
2. Moisture-Density Relation
3. Grain Size Distribution
4. Atterberg Limits

Desired Program (Minimum Program Plus)

1. CBR Test
2. Resilience Test

Lime-Fly ash-Sludge Material

Minimum Program

1. Durability Tests (Loss on F-T ASTM C-593)
2. Strength Test

   Compressive
   Stabilometer 7 Days 100° F
   Cohesiometer
3. Modulus of Deformation
4. Dimensional Stability

Desired Program (Minimum Program Plus)

1. Loss of Strength with Freeze-Thaw
2. Time-Temperature Strength Curves
3. Flexural Strength
4. Split Tensile Strength
5. Effect of Density on Durability and Strength

Surface Material

Minimum Program

1. Stabilometer Valve
2. Cohesiometer

Desired Program (Minimum Program Plus)

1. Marshall Stability
   a) 140° F
   b) 100° F

CONSTRUCTION-QUALITY CONTROL TESTING

Minimum Program

1. Moisture and density testing of the subgrade soil and base materials during placing and compaction.
2. Proof rolling of the subgrade and elimination of soft spots.
3. Density testing of surface material.
4. Mold and break compression specimens with materials taken from the roadbed after spreading.
5. Mold and test durability specimens with material taken from the roadbed after spreading.
6. Validation of thickness of layers.

Desired Program (Minimum Program Plus)

1. Titration testing to determine amount of components in the mix.
2. Extraction tests to check asphalt content of surface.

Laboratory tests are for the purposes of documenting characteristics of materials used in the demonstration pavements. Since other state highway agencies as well as the FHWA will also probably be interested in the data collected, it is recommended that laboratory tests on the materials consist not only of these tests normally conducted by West Virginia Department of Highways, but also the more popular methods of testing used by the other state highway departments. Accordingly, the laboratory testing program is broken into two catagories: a minimum test program, and a desired test program. The proposed test programs are broken down by pavement component.

G. PERFORMANCE AND BEHAVIOR VALIDATION

Maximum benefit can be obtained from the demonstration pavements only if any distresses areas are thoroughly documented as to cause and time of occurrence. This requires frequent inspections and testing by competent, trained observers. Listed below is a recommended minimum program plus a more comprehensive and desired program of pavement inspection and testing.

Minimum Program

1. Inspection by competent engineers on a bimonthly basis for the first year and semiannually or quarterly thereafter.
2. Documentation of all cracks, distressed areas and failures with probable cause as soon as they are observed.
3. Documentation of traffic with emphasis on the number and approximate axle loads of trucks.

Desired Program

1. Deflection measurements with Benkleman beam or vibratory equipment before opening to traffic; preferably every inspection but at least every Spring and every Fall. (Approximately same time each year.)
2. In depth evaluation of the paving materials with samples taken for laboratory analysis on a periodic basis (every 30 to 60 days first year, 90 to 120 days next year, and twice a year after two years.)

H. CONSTRUCTION PROCEDURE

Construction procedures with the lime-fly ash-sludge mixtures are similar to construction procedures used with other paving materials. The four essential steps in the mixing and placement of these materials are:

1. feeding of the components
2. blending of the components
3. placing and spreading of the mixture
4. compaction

1. Feeding of components - The desired quantity of lime, fly ash, sludge, and aggregate if used, shall be as determined by laboratory evaluation for each mix. The component materials will be metered into the mixer using approved methods for each of the components (vane feeders for the lime and sludge and volumetric gate controls for the fly ash and aggregate components). The lime shall be stored in air activated vibratory surge bins. Water shall be added in sufficient quantity to bring the moisture content to optimum plus or minus 2 percent.

2. Blending - Blending of components shall be accomplished in an approved type pug mixer. The mixing time shall be determined in advance by mixing a batch of material for varying periods of time from 15 to 30 seconds and molding compressive specimens shall be cured for the prescribed period of time and tested. The mixing time required is the minimum mixing time required to produce specimens with compressive strength equal to the maximum value.

3. Placing and Spreading - After thorough blending of the components and water, the material shall be transported to the job site and spread uniformly over the prepared roadbed. The spreading can be done with motor patrols, spreader boxes, or by other approved paving material spreaders. The important thing is to obtain a uniform distribution of material over the prepared roadbed.

In spreading the material care shall be taken to prevent feathering of the material near the edges of the pavement. To accomplish this it may be necessary to build up and form the shoulders to the desired level of the compacted base material.

4. Compaction and Finishing - Compaction and finishing shall be done in the manner prescribed in Section 301.3.4.4, West Virginia Department of Highways Standard Specifications Roads and Bridges, adopted 1972 with the following exceptions:

a. Sampling shall be based on approved statistical procedures for sampling in place materials, and compaction shall average 100 percent of the density at which the materials were evaluated in the laboratory evaluation tests with a coefficient of variation of not more than 7 percent for each section sampled.

b. The time elapsed between mixing and final compaction shall be based on results from laboratory tests to determine the effects of lime after mixing on the density of the prepared specimens.

I. REPORTING

Reports on the demonstration pavements shall include results from laboratory tests on the lime-fly ash-sludge mixtures, design calculations and projected performance of the pavement sections, results from quality control tests during construction, results from tests on the lime-fly ash-sludge mixture in place and performance data on the pavement sections as a whole. Any distress observed shall be carefully documented as to extent, time of occurrence, and probably cause. All evidence of longitudinal roughness, transverse roughness, cracking, etc. shall be carefully described and documented.

Appendix C provides a selected bibliography dealing with various investigations that have been made on lime-fly ash-aggregate compositions.

VI. SUMMARY AND CONCLUSIONS

The principal purpose of this study was to investigate and tabulate data relating to the supply and proposed use of lime-fly ash-sludge compositions as an economically feasible and environmentally beneficial substitute for conventional road building materials often in short supply in the West Virginia area. In addition, the desired result of this study program is to ultimately develop specifications for the use of lime-fly ash-sludge compositions as road construction material that would be mutually acceptable to both State and Federal Highway departments.

Upon a thorough study of the data gathered, the use of these lime-fly ash-sludge compositions for road base and other structural compositions appears to be an economically feasible and technically viable alternative to present construction materials. It is well-known that a considerable amount of the money spent for West Virginia highway construction materials goes to out-of-state suppliers. It is felt as a result of this study that introduction of waste processing technology in West Virginia would curtail this substantial flow of West Virginian money out of the state, while at the same time assisting in solving many of the pollution problems, present and potential.

While the advent of strict controls on the emission of SO_2 to the atmosphere, it is likely that West Virginia, a coal-oriented state, will soon be forced to begin the transition to stack gas scrubbing operations to remove this harmful pollutant from the discharged gases produced by its many power stations. With this transition will come the production of millions of tons of scrubber sludges, which in themselves would present an enormous disposal problem. In light of this study, however, it is quite feasible to adapt the lime-fly ash-sludge technology described in this report into processing anticipated production of this material. Clearly, the production of only road base materials in quantities of this magnitude would certainly outdistance the need for such materials, but other potential uses could easily be found to take up the difference. Such alternate uses could be strip mine reclamation, deep mine subsidence, the introduction of a comprehensive road shoulder stabilization program, correction of slips and slides so prevalent in the state, and many others.

VII. RECOMMENDATIONS

Based on the data which have been obtained and evaluated during this project, the following specific recommendations can be made:

1. The use of waste sludges and fly ash in road base construction, road shoulder stabilization, and other structural compositions appears to be an economically and technically viable alternative to present construction materials.

2. The IU Conversion Systems, Inc. Poz-O-Tec™ waste processing technology is adaptable to the processing and utilization of large quantities of sludges produced from SO_2 gas scrubbers, when these sludges become available in West Virginia.

3. Additional work should be initiated to demonstrate the use of Poz-O-Tec™ waste processing technology in the alleviation of other environmental problems, specifically including strip mine reclamation, deep mine subsidence.

4. The incorporation of other waste materials such as slag and mine refuse or spoil banks into the compositions should be considered.

5. A demonstration program should be initiated to allow a thorough evaluation of lime-fly ash-sludge road base compositions under actual traffic conditions. This program would aid in the development of realistic construction requirements and specifications for the compositions.

APPENDIX A

SURVEY OF MINE REFUSE BANKS

WEST VIRGINIA

DISTRICT 3 - MORGANTOWN

WATER IMPOUNDMENT

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Williams Mine Mountaineer Coal Co.	Harrison County - 3/4 mile W of Enterprise, W. Va.	450'	100'	40'	Company expects to provide overflow and drainage facilities
No. 93 Mountaineer Coal Co.	Marion County - 1 mile NE of Rivesville, W. Va.	400'	1000'	80'	
Consol No. 20 Mountaineer Coal Co.	Marion County - ¼ mile SE of Four States, W. Va.	100'	400'	150'	Slurry pond Spillway provided
Loveridge Mountaineer Coal Co.	Marion County - 2-½ miles W of Fairview, W. Va.	750'	750'	75'	Slurry pond spillway and drainage provided
Joanne Eastern Assoc. Coal Co.	Marion County - ½ mile N of Rachel, W. Va.	2000'	700'	60'	Bank separate from impoundments, drainage and pressure relief provided. Impoundments well constructed
No. 41 Bethlehem Mines Corp.	Marion County - ¼ mile NE of Barrackville, W. Va.	1200'	1200'	60'	Slurry pond, overflow and pressure relief provided. Compacted and covered with clay
Arkwright No.1 Christopher Coal Co.	Monongalia County - 1 mile W of Granville, W. Va.	2000'	200'	100'	Impoundment on bank
Humphrey No.7 Christopher Coal Co.	Monongalia County - ½ mile N of Bertha, W. Va.	3600'	800'	60'	Refuse bank compacted and layered with clay
Bunker Christopher Coal Co.	Monongalia County - ½ mile E of Cassville , W. Va.	1800'	200'	20'	
Federal No. 1 Eastern Assoc. Coal Co.	Marion County - ½ mile E of Grant Town, W. VA	5000'	3000'	0-100'	Drainage provided burning compacted slag and clay; 3/4 of impoundment is slag; 26% moisture
Petitte No.1 Pettitte Mining Co.	Monongalia County - ½ mile NW of Maidsville, W. VA	1800'	300'	30'	Burning
Adrian Upshur Coal Corp.	Upshur County - 2 miles E of Adrian, W. VA	2000'	200'	30'	Slurry pond burning

WEST VIRGINIA

DISTRICT 3 - MORGANTOWN

BURNING BANK

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Badger No. 13 Badger Coal Co.	Barbour County - 2 miles E of Philippi	2000'	250'	30'	Burning
Galloway Mine	Barbour County - Galloway on Rt. 76	1500'	1500'	30'	Burning
Beech Bottom Windsor Power House Coal Co.	Brooke County - 1 mile SE of Beech Bottom	2000'	500'	40'	Burning
Dawson Galloway Land Co.	Harrison County - ½ mile NE Dawmont on US 19	2000'	100'	20'	Burning
Norton Mine C. E. Hough Estate (Abandoned)	Randolph County - 1000' E of Norton on US 33	2000'	200'	50'	Burning angle of repose 55°

WEST VIRGINIA

DISTRICT 3 - MORGANTOWN

DRY DUMP

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Ruby No. 4 Ohio Mining Co. (Abandoned)	Barbour County - ½ mile W of Brownton on Rt. 16	250'	150'	90'	
O'Donnell No.2 R & P Coal Co. (Abandoned)	Gilmer County - 2 miles W of Sand Fork on W. VA				
Consol No. 9 Mountaineer Coal Co.	Marion County - 2 miles N of Farmington on Rt. 15	2000'	500'	70'	Full of silt
Federal No.2 Eastern Assoc. Coal Co.	Monongalia County - ½ mile W of Miracle Run on Rt. 17/1	120'	70'	40'	Separate impoundments constructed of clay

WEST VIRGINIA

DISTRICT 4 - MOUNT HOPE

WATER IMPOUNDMENT

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Robinhood Mines 8 & 9 Armco Steel Co.	Boone County - 1 mile SE of Twilight, W. Va.	2400'	100'	300'	Angle of repose, 65°
Prenter Coal Co.	Boone County - ¼ mile SW of Keith, W. Va.	60'	40'	115'	Angle of repose, 70°
Eastern Assoc. Coal Corp.	Boone County - 1-½ mile W of Barrett, W. Va.	300'	12'	96'	
Island Creek Coal Co.	Boone County - 1-½ miles SE of Bobwhite, W. Va.		360'	100'	
Armco Steel Corp.	Boone County - ½ mile NW of Nellis, W. Va.	2500'	300'	150'	Burning, angle of repose 45-70°
Bethlehem Mines Corp.	Boone County - 2-3/4 miles NW of Bandytown, W. Va.	3400'	550'	90'	Burning, angle of repose, 70°
Big Mountain Coal, Inc.	Boone County - 3/4 miles SW of Prenter, W. Va.	1500'	400'	200'	Burning, angle of repose 60°
Westmoreland Coal Co.	Boone County - 7 miles E of Clothier, W. Va.	470'	225'	70'	Burning, angle of repose 60°
Bethlehem Mines Corp.	Boone County - 2-3/4 miles NW of Bandytown, W. Va.	3400'	550'	90'	Burning, angle of repose 60°
Eastern Assoc. Coal Corp.	Boone County - Across Pond Fork From Wharton, W. Va.	700'	1200 -	1400	
Kessler Coal Inc.	Boone County - 2-3/4 miles SW of Whitesville, W. Va.	60'		14'	Concrete Dam
The New River Co.	Fayette County - Just West of Summerlee, W. Va.	400'	180'	9'	
The New River Co.	Fayette County- 4 miles SE of Mt. Hope W. Va.	390'	65'	7'	Inactive
The New River Co.	Fayette County - 4 miles SE of Mt. Hope W. Va.	240'	70'	7'	Inactive
The New River Co.	Fayette County 4 miles SE of Mt. Hope, W. VA	210'	100'	5'	
Riverton Coal Co.	Fayette County - South of McDunn, W. VA	750'	400'		Angle of repose, 54°
Old Duo Mine Island Creek	Greenbrier County - Big Clear Creek Duo, W. VA	800'	60-200'	160'	Water thru base & natural spillway 10' freeboard, burning Angle of repose 64-83°
Old Duo Mine Island Creek Coal Co.	Greenbrier County - Big Clear Creek Duo, W. VA	120'	60'		Spillway too high No fire trails around bank, burning
Carbon Fuel Co.	Kanawha County - ½ mile NE of Wevaco, W. VA		2500'	70'	

WATER IMPOUNDMENT

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Amherst Coal Co.	Logan County - 2-7/8 miles NW of Amherstdale, W. VA	12'	250'	60'	Angle of repose 50°
Amherst Coal Co.	Logan County - 2 miles NW of Amherstdale, W. VA	100'	350'	130'	Angle of repose 60°
Amherst Coal Co.	Logan County - 2-3/4 miles NW of Amherstdale W. VA	18'	300'	60'	Angle of repose 60°
Boone County Coal Corp.	Logan County - ½ mile SE of Montcoal, W. VA	1000'	1400'	400'	Angle of repose 70°
Island Creek Coal Co.	Logan County - 2 miles SE or Blair,W. VA	500'	823'	162'	Burning
Island Creek Coal Co.	Logan County - ½ mile S of Upper Whitman, W. VA		544'	320'	
Island Creek Coal Co.	Logan County - ½ mile S of Upper Whitman, W. VA	300'	533'	293'	Burning
Island Creek Coal Co.	Logan County - Buffalo Creek at Stowe, W. VA		106'	50'	Burning
Island Creek Coal Co.	Logan County - Buffalo Creek at Stowe, W. VA	750'	284'	188'	Burning
Island Creek Coal Co.	Logan County - Buffalo Creek at Stowe, W. VA	750'	111'	91'	Burning
Wheeling Pittsburgh Steel Corp.	Logan County - ½ mile NE Stirrat, W. VA	1400'	1200'	450'	Burning
Youngstown Mines Corp.	Logan County - Rt. Fork Rum Creek at Dehue, W. VA	185'	400'	105'	Burning
Island Creek Coal Co.	Logan County - Right Fork of Pine Cr. 5 miles W of Omar, W. VA	800'	100'	150'	Burning
Island Creek Coal Co.	Logan County - 3/4 miles W. of Verdunville W. VA	15'	400'	15'	Burning
Island Creek Coal Co.	Logan County - NW end of Sycamore, W. VA	600'	400'	40'	Burning
Island Creek Coal Co.	Logan County - NW end of Sycamore, W. VA	1200'	400'	50'	Burning
Island Creek Coal Co.	Logan County - E end of Emmett on Elk Creek		839'	146'	Burning
Buffalo Mining Co.	Logan County - Middle Fork of Buffalo Creek at Saunders, W. VA		No Data		Burning
Amherst Coal Co.	Logan County - ½ mile S of Amherstdale, W. VA	1250'	100'	75'	Burning

WATER IMPOUNDMENT

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Pocahontas Fuel Co.	Mercer County - ½ mile SW of McComas, W. VA	350'	1100'		
Pocahontas Fuel Co.	Mercer County - ½ mile N Dott, W. VA	2100'	200'	100'	
Bishop Coal Co.	McDowell County - 3/4 mile W of Bishop, W. VA	2000'	2000'	130'	Dam located in W. VA Impoundment in VA Refer to Dist. 5, Richland, VA, Tazewell Co., Pounding Mill Quad A 36.
Keystone No. 1 Mine Eastern Assoc. Coal Co.	McDowell County - ½ mile N of Deystone, W. VA	1500'	600'	200'	Burning
Olgo Coal Co.	McDowell County - 1 mile N of Caretta, W. VA, Rt 16	1500'	300'	150'	Burning
Pocahontas Fuel Co.	McDowell County - 1 mile S of Jenkinjones, W. VA	550'	40'	200'	2 ponds, angle of repose 70°
Pocahontas Fuel Co.	McDowell County - ½ mile NW Payeton, W. VA	300'	700'	150'	Burning
United Pocahontas Fuel Co.	McDowell County - 1-½ mile NE Algoma, W. VA	600'	300'	150'	
United Pocahontas Fuel Co.	McDowell County - ½ mile N Crumpler, W. VA	125'	40'		Sludge ponds
U.S. Steel Corp.	McDowell County - 1 mile NE Wilcoe, W. VA on Grapevine BR.	1500'	600'	150'	Burning
Unknown	McDowell County - 1-3/4 mile NE Anawalt, W. VA				
Cannelton Coal Co.	McDowell County - 3/4 mile SE Superior, W. VA		No Data		Burning
Island Creek Coal Co.	Mingo County - 1 mile NW Newton, W. VA	300'	240'	84'	Burning
National Coal Mining Co.	Mingo County - ½ mile SE Ragland on Rockhouse Fork	400'	20'	100'	Burning, angle of repose 65°
National Coal Mining Co.	Mingo County - ½ mile SE Ragland on Rockhouse Fork	200'	1000'	60'	Burning
Island Creek Coal Co.	Mingo County - 1-½ miles SE Ragland W. VA		No Data		
Island Creek Coal Co.	Mingo County - 1-½ miles SE Ragland, W. VA		No Data		
Sycamore Mining Co.	Mingo County - ½ mile NE Cinderella, W. VA	100'	250'	100'	Burning
Island Creek Coal Co.	Nicholas County - ½ mile NW Marybill, W. VA	1900'	500'	120'	3 sludge ponds, 13 million gals. 5 million gals.,2 million gals. Angle of repose 70°

WATER IMPOUNDMENT

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Sewell Coal Co.	Nicholas County - S of Nettie, W. VA				
Island Creek Coal Co.	Nicholas County - McMillion Cr at Werth, W. VA	300'	1000'	110'	Burning
Island Creek Coal Co.	Nicholas County 1-5/8 mile SW of Tioga, W. VA	2400'	2400'	200'	Burning
Mine No. 7 Armco Steel Corp.	Raleigh County - 1-½ mile NW of Montcoal, W. VA				
Armco Steel Corp.	Raleigh County - Montcoal, W. VA		800'	200'	
Kopperston Pond Eastern Assoc. Coal Co.	Wyoming County - 3/4 mile NE Kopperston, W. VA	2000'	200'	125'	
No. 9 Coal Mtn Island Creek Coal Co.	Wyoming County - ½ mile E of Coal Mtn. W. VA		300'	118'	Burning
Eastern Assoc. Coal Co.	Wyoming County - 3/4 mile NE of Kopperston W. VA Rt. 85	300'	200'		Burning

WEST VIRGINIA

DISTRICT 4 - MOUNT HOPE

BURNING BANK

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Bethlehem Mines Corp.	Boone County - 3/4 mile NE of Hewett, W. VA		No Data		Burning
Ridgeview Coal Co.	Boone County - Ridgeview, W. VA	1200'	250'	150'	Burning, angle of repose 60°
Prenter Coal Co.	Boone County - ¼ mile SW of Keith, W. VA	1500'	75'	80'	Burning, angle of repose 60°
Detroit Mining Co.	Boone County - White's Br. at Gordon, W. VA	1500'	10-20'	1500'	Burning
Eastern Assoc. Coal Corp.	Boone County - Jarrels Branch, W. VA	300'	12/5'	96'	Burning
Westmoreland Coal Co.	Boone County - 7 miles E of Clothier, W. VA	200'	200'	60'	Burning, angle of repose 60°
Westmoreland Coal Co.	Boone County - 7 miles E of Clothier, W. VA	50'	80'	50'	Burning, angle of repose 60°
Omar Mining Co.	Boone County - 8 miles E of Madison, W. VA	800'	50'	75'	Burning

BURNING BANK

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Kessler Coals, Inc.	Boone County - 2-½ miles SW of Whitesville, W. VA	1600'		80'	Burning
Eastern Associated Coal Corp.	Boone County- 4 miles NW of Kopperston, W. VA	1,200,000 Tons			Burning
Millburn Colliery Co.	Fayette County - ½ mile SW of Millburn W. VA	800'	400'	80'	Burning
Westmoreland Coal Co.	Fayette County - 1 mile NW of Landisburg, W. VA	2000'	135'	30'	Burning
Royal Coal Co.	Fayette County - just N of Layland W. VA	1500'	500'	75'	Burning
Hauley Coal Mining Co.	Fayette County - 1 mile E of Beards Fork, W. VA	1000'	800'	500'	Burning
The New River Co.	Fayette County - just NW of Summerlee W. VA	3000'	300'	100'	Burning
Oak Mines	Fayette County - NE of Carlisle, W. VA	1000'	300'	50'	Burning
The New River Co.	Fayette County - Whipple Junction, W. VA	500'	600'	40'	Burning
Riverton Coal Co.	Fayette County - Elkridge, W. VA	660'	460'		Burning, angle of repose 54°
Union Carbide Corp.	Danawha County - 3/8 miles E of Amelia, W. VA		No Data		Burning
Imperial Colliery Co.	Kanawha County - 3/8 mile W of Burnwell, W. VA	100'	100'	250'	Burning
Imperial Colliery Co.	Kanawha County - 3/8 mile W of Burnwell, W. VA	1600'	125'	40'	Burning
Island Creek Coal Co.	Logan County - Proctor Hollow at Amherstdale, W. VA	200'	1000'	300'	Burning
Island Creek Coal Co.	Logan County - Buffalo Creek at Robinette, W. VA		No Data		Burning
Island Creek Coal Co.	Logan County - ½ mile E Scarlet, W. VA		No Data		Burning
Powellton Co.	Logan County - 2 miles SW of Man, W. VA		No Data		Burning
Snap Creek Coal Co.	Logan County - across Guyandotte River from Earling, W. VA	1500'	70'	50'	Burning
Chafin Coal Co.	Logan County - Rita, W. VA	1000'	150'	25'	Burning
Elkay Mining Co.	Logan County - NE end of Earling, W. VA		No Data		Burning
Five Block Coal Co.	Logan County - ½ mile NW Fort Branch, W. VA		No Data		Burning

BURNING BANK

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Jewel Eagle Coal Corp.	Logan County - ½ mile up Badmill Hollow	1500'	100'	100'	Burning
Omar Mining Co.	Logan County - ½ mile E Superior Bottom, W. VA	1500'	150'	200'	Burning
Five Block Coal Co.	Logan County - Wanda, W. VA	2000'	50'	50'	Burning
Powellton Co.	Logan County - 2 miles SW of Man, W. VA	300'	100'	125'	Burning
Powellton Co.	Logan County - 2 miles SW of Man, W. VA	2500'	100'	125'	Burning
Hawley Coal Co.	McDowell County - ½ mile NW Arista, W. VA		No Data		Burning
Pocahontas Fuel Co.	McDowell County - 2 miles NE Maybeury W. VA	3200'	200'	200'	Burning
Unknown	McDowell County - ½ mile W of Bradshaw, W. VA	5000'			Burning
Unknown	McDowell County - ½ mile SW Hartwell, W. VA	200'	200'	40'	Burning
Pocahontas Fuel Co.	McDowell County - 3 miles S Vallscreek, W. VA	1200'	200'	100'	Burning
Pocahontas Fuel Co.	McDowell County - 3/4 miles SE Berwind, W. VA		No Data		Burning
Hawley Coal Co.	McDowell County - ½ mile N of Landgraff, W. VA		No Data		Burning
Unknown	McDowell County - Havaco, W. VA		No Data		Burning
Royalty Smokeless Coal Co.	McDowell County - 3/4 mile NE Havaco, W. VA		No Data		Burning
U.S. Steel Corp.	McDowell County - ½ mile NW Elbert, W. VA		No Data		Burning
U.S. Steel Corp.	Mingo County - Cedar, W. VA		No Data		Burning
Dash Coal Co.	Mingo County Gilbert, W. VA				
Kimberling Collieries Coal Co.	Mingo County - within Verner, W. VA	1	No Data		Burning
Gilbert Imported Hardwoods	Mingo County - 1-3/8 miles E of Gilbert, W. VA	300'	75'	40'	Burning
Sewell Coal Co.	Nicholas County - Marybill, W. VA	2000'	200'		Burning
Island Creek Coal Co.	Nicholas County - ½ mile NW Mary bill, W. VA	300	200'	75'	Burning, Red Dog being removed

BURNING BANK

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Sewell Coal Co.	Nicholas County - South of Nettie, W. VA	1200'	400'		Burning
Sewell Coal Co.	Nicholas County - South of Nettie, W. VA	400'	400'		Burning
Island Creek Coal Co.	Nicholas County - Jetsville, W. VA	4600'	700'	150'	Burning
Peerless Eagle Coal Co.	Nicholas County - ½ mile N of Enon, W. VA			100'	Burning
Westmoreland Coal Co.	Raleigh County - 3/4 mile NE of Eccles, W. VA	700'	400'	20'	Burning
Westmoreland Coal Co.	Raleigh County - Eccles, W. VA	1500'	700'	30'	Burning
Westmoreland Coal Co.	Raleigh County - ½ mile nE of Eccles, W. VA	1200'	325'	100'	Burning
Ranger Fuel Corp.	Raleigh County - 3 mile NE of Ravencliff, W. VA		No Data		Burning
Ameagle Tipple Emerson Stover	Raleigh County - 7/8 mile SE of Ameagle, W. VA		No Data		Burning
Bethlehem Mines Corp.	Raleigh County - 3/8 mile SE of Marfork, W. VA		No Data		Burning, angle of repose, 45°
Sterling Smokeless Coal Co.	Raleigh County - N of Whitby, W. VA	300'	500'	250'	Burning, angle of repose 40°
Affinity Mining Co.	Raleigh County - N of Affinity, W. VA	400'	300'	20'	Burning
Westmoreland Coal Co.	Raleigh County - 3/4 mile NE of Stotesbury, W. VA		No Data		Burning
The New River Co.	Raleigh County - ½ mile N of Stanaford, W. VA	400'	300'	20'	Burning, angle of repose 45°
Prep Plant Island Creek Coal Co.	Webster County - 4 miles SE Dyer, W. VA	600'	180'	100'	Burning, angle of repose 75°
Island Creek Coal Co.	Wyoming County - 1 mile S of Wyco, W. VA		No Data		Burning
Robinson Phillips Coal Co.	Wyoming County - 1-½ miles S Baileysville, W. VA		No Data		Burning
Abandoned Mine Dump (Garbage Dump)	Wyoming County - 1 mile S of Wyoming, W. VA		No Data		Burning
Buckeye Colliery Pocahontas Fuel Co.	Wyoming County - 3/8 mile S of Stephenson, W. VA	2600'	50'	75'	Burning
Westmoreland Coal Co.	Wyoming County - 2 miles NE of Pierpont, W. VA	500'	30'	30'	Burning
Westmoreland Coal Co.	Wyoming County - 2 miles NE of Pierpont, W. VA	3100'	125'	100'	Burning
Eastern Assoc. Coal Co.	Wyoming County - 3/8 mile NE of Covel, W. VA	800,000 Tons			Burning

WEST VIRGINIA

DISTRICT 4 - MOUNT HOPE

DRY DUMP

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Kessler Coals, Inc.	Boone County - 2-½ miles SW of Whitesville, W. VA		No Data		Angle of repose 40°
Kessler Coals, Inc.	Boone County - 2 miles SW of Whitesville, W. VA		No Data		Angle of repose 30-40°
The Pittston Co.	Clay County - 3/4 mile SE of Widen, W. VA		No Data		
The Pittston Co.	Clay County - 7/8 mile SE of Buffalo Creek	5000'	500'	150'	Angle of repose 65°
Allied Chemical Corp.	Fayette County - Long Acre, W. VA		No Data		
The New River Co.	Fayette County - NW of Summerlee, W. VA	500'	500'	40'	
Riverton Coal Co.	Fayette County - Mayan, W. VA		No Data		Inactive angle of repose 60°
Riverton Coal Co.	Fayette County - 1/3 mile South of Elkridge, W. VA	310'	110'		Angle of repose 56°
Riverton Coal Co.	Fayette County - ½ mile SW of Elkridge, W. VA	600'	300'		Angle of repose 54°
Riverton Coal Co.	Fayette County - 5/8 mile S of Elkridge, W. VA	480'	310'		Angle of repose, 52°
Riverton Coal Co.	Fayette County - 1-½ mile S of McDunn, W. VA	1080'	100'	20-25'	
Riverton Coal Co.	Fayette County - 3/4 mile SE of Mahan, W. VA	340'	330'		Angle of repose, 76°
Riverton Coal Co.	Fayette County - 3/ 4 mile SE of Mahan, W. VA	540'	520'		Angle of repose, 68°
Riverton Coal Co.	Fayette County - 3/4 Mile SE of Mahan, W. VA	160'	190'		Angle of repose 57°
Riverton Coal Co.	Fayette County - 1-1/8 mile SE of Mahan, W. VA	460'	310'		Angle of repose 63°
Critchton No. 1 Mine Island Creek Coal Co.	Greenbrier County - Meadow Creek, Rt. 20 Critchton, W. VA	520'	350'	150'	
Pocahontas Mine New River & Pocahontas Fuel Co.	Greenbrier County - Leslie, W. VA	750'	60-180'		Angle of repose 34-73°

DRY DUMP

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
Carbon Fuel Corp.	Danawha County - 2-½ mile S of Winifede, W. VA		No Data		
Island Creek Coal Co.	Logan County - Proctor Hollow at Amherstdale, W. VA	600'	200'	150'	Angle of repose 50°
Jewel Eagle Coal Co.	Logan County - ½ mile up Badmill Hollow	600'	50'	50'	
Chafin Coal Co.	Logan County - on Laurel Fork of Omar, W. VA		No Data		
Omar Mining Co.	Logan County - 1 mile W of Omar, W. VA	1500'	150'	50'	
Amherst Coal Co.	Logan County - Amherstdale,W. VA	1000'	1 200'	175'	Angle of repose 50°
Mary Lynn Coal Co.	McDowell County - ½ mile E Powhatan, W. VA	550'	30'	40'	
Hawley Mining Co.	McDowell County - Squire, W. VA		No Data		
Nos. 2&7 Mines Westmoreland Coal Co.	Nicholas County - Colt Br. of Hominy Creek	2000'	100'	200'	
Pittston Coal Co.	Nicholas County - ½ mile S Mary bill, W. VA		No Data		Angle of repose 68°
Pittston Coal Co.	Nicholas County - 1-3/4 miles SE Mary bill, W. VA		No Data		Angle of repose 68°
No. 1 Prep Plant Island Creek Coal Co.	Nicholas County - Vestaville, W. VA		No Data		Angle of repose 64°
No. 19 Pittston Coal Co.	Nicholas County - 1-½ miles NW Holcomb, W. VA	2400'	1700'	450'	
Consolidation Coal Co.	Raleigh County - 2-3/8 miles SW of Clear Creek, W. VA			110'	
Westmoreland Coal Co.	Raleigh County - 1 mile NE of East Gulf, W. VA	270'	12'	120'	
Eastern Assoc. Coal Co.	Raleigh County - ½ mile N of Stotesbury, W. VA		No DAta		
Island Creek Coal Co.	Webster County - 4 miles SE Dyer, W. VA	300'	200'	40'	Angle of repose 65°
Pittsburgh & Redstone Fuel Co.	Webster County - 3/4 miles S Bergoo, W. VA	500'			Angle of repose 60°
Bolair Prep Plant Parde & Curtins Coal & Limber Co.	Webster County - Bolair, W. VA	400'	350'	150'	

DRY DUMP

SITE & OWNER	LOCATION	SIZE OF BANK			REMARKS
		Length	Width	Height	
No. 2 Mine Parde & Curtins Coal Co.	Webster County - 3/ 4 miles SE Curtin, W. VA		No Data		Angle of repose 68°
Island Creek Coal Co.	Webster County - 3-½ miles E Jerryville, W. VA		No Data		Angle of repose 72°
No. 9 Coal Mtn. Island Creek Coal Co.	Wyoming County - ½ mile E Coal Mtn., W. VA		No Data		
Lynco Dump Pocahontas Fuel Co.	Wyoming County - 1-½ miles SE Lynco, W. VA, Rt. 7/1	400'	300'		
Itmann Dump Itmann Coal Co.	Wyoming County Itmann, W. VA		600'		
Westmoreland Coal Co.	Wyoming County - Otsego, W. VA	500'	600'	200'	Angle of repose 45°
Eastern Assoc. Coal Corp.	Wyoming County - Montecarlo, W. VA		3,440,000 tons		
Eastern Assoc. Coal Corp.	Wyoming County - Montecarlo, W. VA		316,000 tons		Angle of repose 40°

APPENDIX B

CURRENT REQUIREMENTS OF HIGHWAY CONSTRUCTION AGGREGATES

Class 1 Aggregate Base Course

Sieve Size	% Thru
1½"	100
3/4"	50-90
#4	20-50
#40	5-20
#200	0-7

Los Angeles Abrasion, Percent, Max.	50
Sodium Sulfate Soundness, Percent, Max.	12
Liquid Limit, Percent, Max.	25
Plasticity Index, Percent, Max.	6
Deleterious Material, Percent, Max.	5

Class 2 Aggregate Base Course

Sieve Size	% Thru
1½"	100
3/4"	80-100
#4	35-75
#40	10-30
#200	0-10

Los Angeles Abrasion, Percent, Max	50
Sodium Sulfate Soundness, Percent, Max.	12
Liquid Limit, Percent, Max.	25
Plasticity Index, Percent, Max.	6
Deleterious Material, Percent, Max.	5

Class 3 Aggregate Base Course

Sieve Size	% Thru
1½"	100
3/4"	50-90
#4	20-50
#40	5-25
#200	4-15

Los Angeles Abrasion, Percent, Max.	50
Sodium Sulfate Soundness, Percent, Max.	12
Liquid Limit, Percent, Max.	25
Plasticity Index, Percent, Max.	6
Deleterious Material, Percent, Max.	5

Grade 1 Subbase Aggregate

Sieve Size	% Thru
2"	100
#4	30-90
#200	0-25

Los Angeles Abrasion, Percent, Max.	*Note 1
Sodium Sulfate Soundness, Percent, Max.	-
Deleterious Material, Percent, Max.	10

*Note 1 The Los Angeles Abrasion Value of aggregate comprising the base course shall be treated in the manner hereinafter set forth to determine the specification requirement for the item.

Los Angeles Abrasion Value Assigned to the Base Course Aggregate	Stabilization Requirements
LA 50	None
50 LA 65	Top 4 inches
65 LA 80	Top 6 inches
80 LA	Top 8 inches

Grade 2 Subbase Aggregate

"Grade 2 subbase aggregate shall be composed of stream bed or pit gravel, shale, chert, or red dog, unless one type is specifically called for on the Plans.

The material shall not have a maximum dimension greater than 2/3 the thickness of the course being placed. The material shall not contain more than 10 per cent by weight of coal, clay, or other deleterious substances. The plasticity index shall not be greater than 6 as determined by ASTM D 424 and the liquid limit not greater than 25 as determined by ASTM D 423, both reported to the nearest whole number."

Class 7 Aggregate Stone (Base) Type A

Top size $1\frac{1}{2}$"

Los Angeles Abrasion, Percent, Max.	65
Sodium Sulfate Soundness, Percent, Max.	35
Plasticity Index, Percent, Max.	6

APPENDIX C

PARTIAL BIBLIOGRAPHY ON USE OF LIME-FLY ASH-AGGREGATE MIXTURES

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